U.S. Department Of Energy

San Francisco Operations Office, Oakland, California 94612

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UCRL-AR-115997

Remedial Design Report No. 6 for the Building 518 Vapor Treatment Facility Lawrence Livermore National Laboratory Livermore Site

November 30, 1994

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Environmental Protection Department

Environmental Restoration Division

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Summary

This is the fourth of six reports that describe plans for ground water and soil cleanup at the Lawrence Livermore National Laboratory (LLNL) Livermore Site. The cleanup has been divided into 9 geographic areas with 11 treatment facilities. The Department of Energy (DOE) and LLNL are preparing these reports, called Remedial Design reports, over a 5-year period. The cleanup plans described in each report are designed to optimize the overall site cleanup and be consistent with projected funding levels. The overall cleanup approach for the LLNL Livermore Site is explained in the Remedial Action Implementation Plan, which can be found in the Information Repositories located at the LLNL Visitors Center and at the Livermore Public Library.

This Remedial Design Report No. 6 is for the Building 518 Vapor Treatment Facility in the southeast quadrant of the Livermore Site. This report was added in December 1993 in consultation with the regulatory agencies. At that time, it was agreed that this report would be presented prior to Remedial Design Reports Nos. 4 and 5.

This report presents the wellfield and treatment facility designs and the equipment for the Building 518 Area vadose zone (the unsaturated soil above the water table). As discussed in Remedial Design Report No. 2, ground water from the Building 518 Area will be treated at Treatment Facility F, about 1,000 feet west of the Building 518 Area. Vapor extraction wells will be used to remove soil vapor containing contaminants to the treatment facility for remediation. Vapor extraction well designs are similar to ground water monitoring wells, except the screened interval is in the vadose zone and not in the ground water. Vadose zone probes are used to monitor pressure changes in the subsurface that result from vapor extraction. Monitoring the pressure changes in the probes provides information about the size of the area being affected by the vapor extraction wells.

The purpose of the Building 518 Vapor Treatment Facility is to extract and treat the vadose zone volatile organic compounds, and to ensure that the residual contaminant concentrations in soil are below those predicted to cause contaminant levels in the ground water to be above drinking water standards. The predominant contaminants in the Building 518 Area vadose zone are trichloroethylene, perchloroethylene, and 1,1-dichloroethylene.

A soil vapor extraction test was conducted in June 1993 to design a system to remediate volatile organic compounds in the Building 518 Area vadose zone. For the extraction test, a vacuum was applied to a vadose zone extraction well to remove vapors from the soil, and the vapor was treated by granular activated carbon. This test indicated that vapor extraction can effectively mobilize volatile organic compounds and that granular activated carbon can successfully remove the volatile organic compounds from the vapor. The results of this test were discussed in Remedial Design Report No. 3, and are included in Appendix B of this report.

The data from the soil vapor extraction test, along with site-specific data, were used in a flow and transport model to aid in the wellfield and treatment system designs for the

Building 518 Area. Simulations assuming homogeneous and heterogeneous soil types were evaluated. The homogeneous soil simulation estimated that cleanup would take about 3 to 4 years, whereas the heterogeneous simulation estimated about 5 to 6 years for cleanup. Modeling results also indicated that the treatment facility should be designed to remediate about 100 standard cubic feet of soil vapor per minute.

The Building 518 Vapor Treatment Facility is designed to remediate up to 150 standard cubic feet of soil vapor per minute. As many as three soil-vapor extraction wells are planned to supply vapor to this facility. Treated vapor from the facility will meet the conditions set by the Bay Area Air Quality Management District. Although the air discharge permit will not be issued until the facility begins operations, the Authority to Construct air discharge conditions are provided in Appendix E of this report

The Building 518 Vapor Treatment Facility is scheduled to begin operation on September 29, 1995. The estimated total design and construction cost of the facility is about $110,000.

DOE/LLNL will sample the extracted vapor for volatile organic compounds and monitor soil vapor pressure changes in nearby vadose zone probes. This information will be used to monitor the progress of the cleanup and determine the size and shape of the region being affected by the vapor extraction wells. Ongoing modeling will also be used to periodically evaluate system performance and estimate the cleanup time. Results of all treatment system, extraction well, and vadose zone probe monitoring and the periodic modeling will be included in the LLNL Monthly, Quarterly, and/or Annual Reports.

Appendices to this report contain soil and ground water analytical results for the Building 518 Area, a summary of the vapor extraction treatability test, treatability test mass removal calculations, details of the vadose zone flow and transport model, the Authority to Construct air effluent discharge conditions, and sampling procedures for the treatment facility. The appendices also contain the Quality Assurance and Health and Safety Plans for the operation and maintenance of the Building 518 Vapor Treatment Facility. The Quality Assurance/Quality Control and Health and Safety Plans for construction were presented in Remedial Design Report No. 1.

1. Introduction

This report is the fourth of six Remedial Design (RD) reports prepared for the Lawrence Livermore National Laboratory (LLNL) Livermore Site, which is located about 40 miles east of San Francisco, California (Fig. 1). This sixth report, for the Building 518 (B-518) Area in the southeastern part of the Livermore Site, was added in December 1993 in consultation with the regulatory agencies. At that time, it was agreed that this report would be issued prior to RD Report Nos. 4 and 5. The subsequent RD reports will cover the remaining planned treatment facilities and their extraction well and piezometer networks. The six RD reports are being prepared over a 5-y period. As described in the Remedial Action Implementation Plan (RAIP) (Dresen *et al.*, 1993), the remedial actions presented in the Record of Decision (ROD) for the Livermore Site (DOE, 1992) will be phased-in to be consistent with projected funding levels, and to enable determination of the actual, rather than predicted, effectiveness of the planned extraction and treatment systems before proceeding with subsequent phases.

The Livermore Site was placed on the U.S. Environmental Protection Agency's (EPA's) National Priorities List in 1987. In November 1988, the U.S. Department of Energy (DOE), EPA, the California Department of Toxic Substances Control (DTSC), and the California Regional Water Quality Control Board (RWQCB) signed a Federal Facility Agreement (FFA) to facilitate compliance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended. As part of the CERCLA process, the LLNL Environmental Restoration Division (ERD) has prepared a series of documents: the Remedial Investigation (RI) (Thorpe *et al*., 1990) characterized the site hydrogeology and contaminant distribution; the Feasibility Study (FS) (Isherwood *et al*., 1990) screened and evaluated possible remedial alternatives; the Proposed Remedial Action Plan (Dresen *et al*., 1991) further evaluated conceptual remedial alternatives and recommended particular alternatives for ground water and soil cleanup; the ROD (DOE, 1992) codified and bound DOE and EPA to a cleanup approach for ground water and soil; and the RAIP (Dresen *et al*., 1993) presented the cleanup approach and a schedule for the remaining remedial actions.

As discussed in the ROD, the contaminants of concern at the Livermore Site are volatile organic compounds (VOCs), primarily trichloroethylene (TCE) and perchloroethylene (PCE); fuel hydrocarbons (FHCs), including benzene; tritium; and perhaps chromium and lead. VOCs are the only chemicals of concern in the B-518 vadose zone. The Applicable or Relevant and Appropriate Requirements (ARARs) for the Livermore Site are detailed in the FS and the ROD.

The scope of the RD reports is based on EPA guidance documents (EPA, 1989; 1990), an outline provided by EPA (Gill, 1993), and subsequent discussions with EPA and the other regulatory agencies. As specified by EPA, each RD report contains engineering design specifications for the treatment systems, including piping and instrument diagrams (P&IDs), system descriptions, monitoring and construction schedules, and cost estimates. The RD reports also include a Remedial Action Workplan that contains Quality Assurance/Quality Control (QA/QC) Plans and Health and Safety Plans (HASPs) for facility operation and maintenance, and the requirements for offsite shipment of hazardous waste and for project closeout. The QA/QC HASPs for construction are the same for all RD reports. Therefore, these documents were submitted only with Remedial Design Report No. 1 (RD1) (Boegel *et al*., 1993).

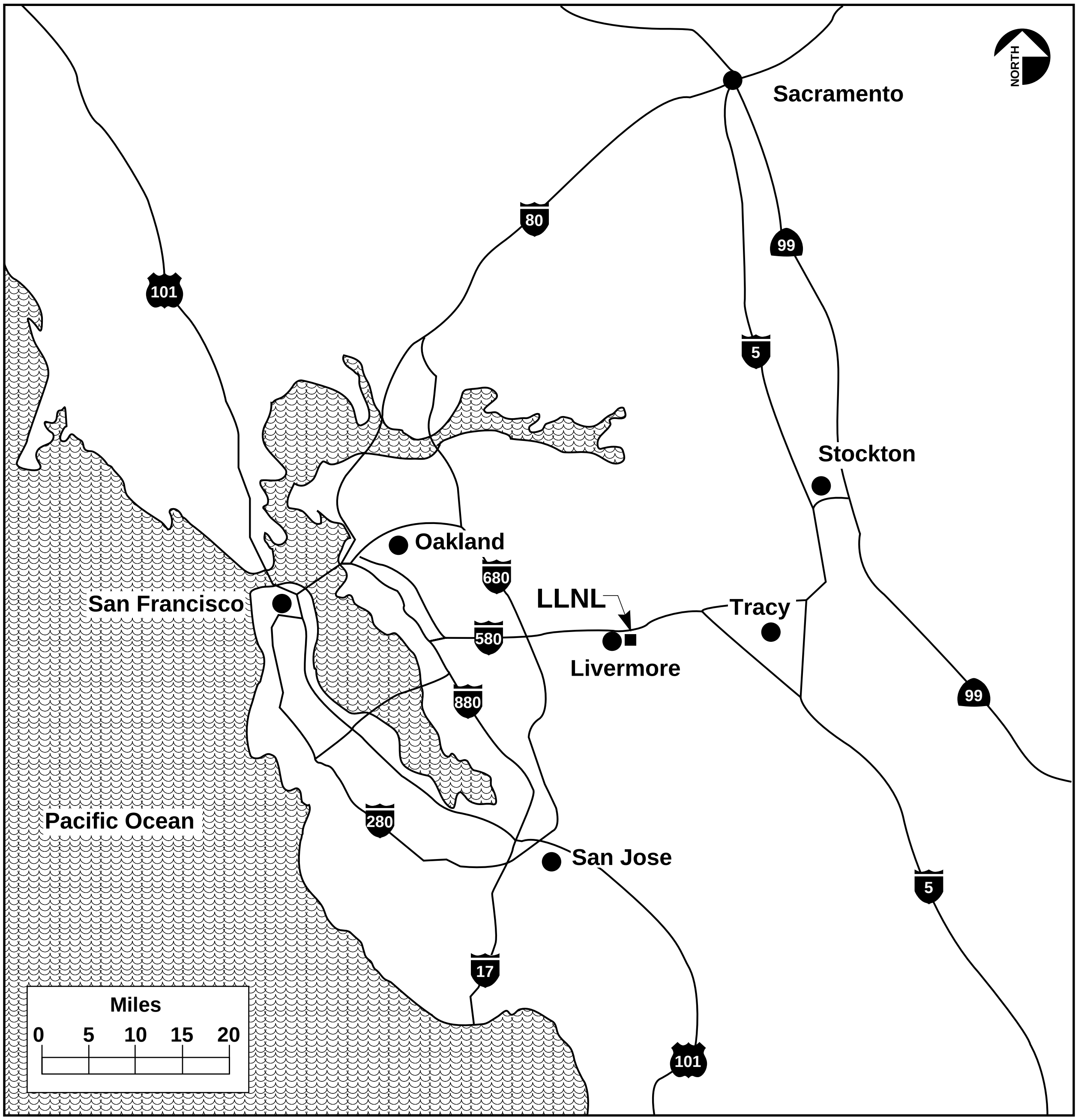

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Figure 1. Location of the LLNL Livermore Site.

This document was prepared by DOE/LLNL with oversight from EPA, DTSC, and RWQCB. The six RD reports are primary documents under the FFA for the Livermore Site.

This report presents the remedial design for the B-518 Vapor Treatment Facility. As stated in the RAIP (Dresen *et al.*, 1993), soil vapor extraction (SVE) at extraction location 18 (B-518 Area) (Fig. 2) is planned for areas where VOC concentrations in unsaturated soil may impact ground water concentrations above a Maximum Contaminant Level (MCL). Modeling of VOC migration from the vadose zone to the ground water (Isherwood *et al.*, 1990) indicates that VOCs in the vadose zone in this area could impact the ground water in concentrations above MCLs. As discussed in Remedial Design Report No. 2 (RD2) (Berg *et al.*, 1993), ground water from the B-518 Area will be treated at Treatment Facility F (TFF) (Fig. 2).

Section 2 of this report discusses the evaluation and design of the B-518 Vapor Treatment Facility extraction wellfield. Section 3 presents the treatment facility design. Section 4 is the Remedial Action Workplan for the B-518 Vapor Treatment Facility. Soil and ground water analytical results, a summary of the treatability test, mass removal calculations, and details of the vadose zone flow and transport model are presented in Appendices A, B, C, and D, respectively. Because the air discharge permit will not be issued until after the facility begins operation, Appendix E presents the Authority to Construct air discharge conditions. Appendices F through H present the Operations and Maintenance (O&M) QA/QC Plan, O&M HASPs, and sampling procedures for the B-518 Vapor Treatment Facility, respectively.

2. B-518 Soil Vapor Extraction Wellfield Design

The B-518 SVE wellfield design is based on VOC distribution data, stratigraphic analyses, treatability tests, and flow and transport modeling. Each of these is discussed in Sections 2.1 through 2.4. The final wellfield design is presented in Section 2.5.

2.1. Stratigraphic Units in the B-518 Area

The B-518 Area is underlain by the Plio-Pleistocene Livermore Formation. The Livermore Formation is locally subdivided into Upper and Lower Members (Thorpe *et al.*, 1990). The Upper Member is characterized by oxidized reddish-brown to brown gravel beds, with lesser sand, silt, and clay, and is overlain by lithologically indistinguishable younger sediments. The Lower Member consists of three recognizable units: a transition zone characterized by both oxidized (reddish) and reduced (blue/green) colors, a green unit, and a blue unit. The upper part of the Lower Member is characterized by green to blue silt and clay with occasional gravel beds. These regional geologic units were subdivided into hydrostratigraphic units as discussed below.

The hydrostratigraphic units defined in Remedial Design Report No. 3 (RD3) (Berg *et al.*, 1994) for the Treatment Facility D and E (TFD and TFE) areas were identified in the B-518 Area. The use of hydrostratigraphic units reflects ongoing work to interpret and synthesize the Livermore Site hydrogeology on a site-wide basis, and represents a logical progression from the use of borehole-specific water-bearing zones to units with more regional extent. After completion of all RD reports, a report is planned that will summarize the Livermore Site hydrostratigraphy. Preliminary wellfield designs presented in RD reports may be modified based

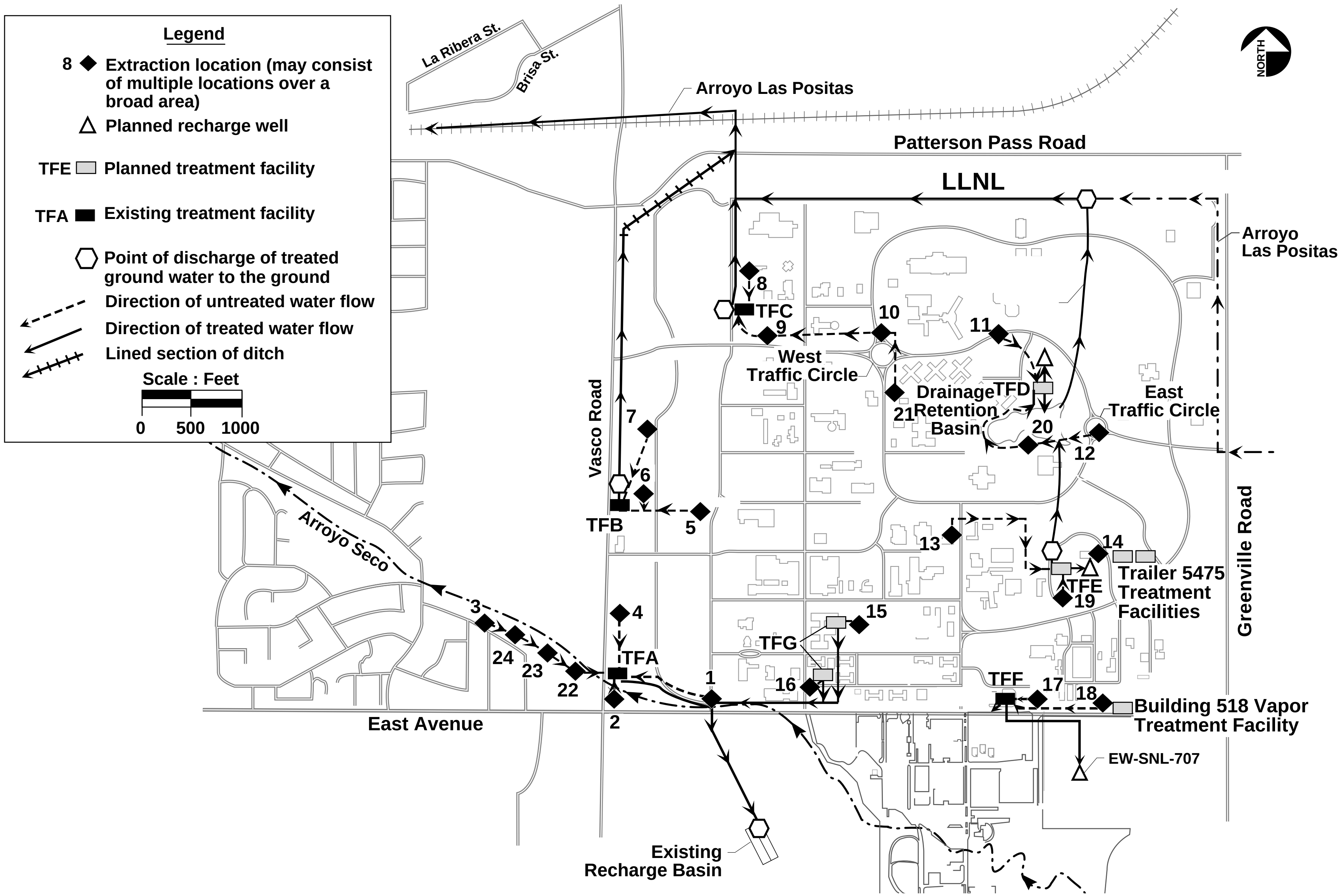

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Figure 2. Planned and existing treatment facilities and ground water extraction locations at the Livermore Site (modified from the RAIP).

on new information or interpretations presented by DOE/LLNL staff or after discussion with the regulatory agencies.

In RD3, six hydrostratigraphic units were defined in the TFD and TFE areas (Fig. 2) based on analysis of hydraulic test data, soil and ground water chemical data, borehole lithologic descriptions, and borehole geophysical logs. Similar analyses were performed for the B-518 Area to understand VOC distribution, local stratigraphy, and to select preliminary SVE well locations. Comparison of the geophysical and lithologic character of the stratigraphic units in the B-518 Area to the hydrostratigraphic units in the southern TFE Area indicates that the units in the B-518 Area are laterally continuous with the hydrostratigraphic units defined in the southern part of the TFE area. However, the hydrostratigraphic units in the B-518 Area occur at much shallower depths and are largely unsaturated, as the water table occurs within the fifth hydrostratigraphic unit that is only partially saturated in the eastern B-518 Area. Therefore, hydrostratigraphic units defined at TFD and TFE that are unsaturated in the B-518 Area are referred to as stratigraphic units in this report.

Twenty-five boreholes have been drilled in the B-518 Area. Three are completed as monitor wells, one as a ground water piezometer, and four as SVE wells or vadose zone probes (Fig. 3). The boreholes were drilled in 1984, 1989, 1990, and 1993. The lithologic and VOC data from selected boreholes are shown along east-west cross section A-A' (Figs. 3 and 4). VOC data from soil and ground water analyses are presented in Appendix A.

The first stratigraphic unit (Unit 1) in the B-518 Area is a 60- to 70-ft-thick interval of interbedded silty, gravelly sand and silt, and clayey silt (Fig. 4). A high-resistivity geophysical log response and a low gamma ray response are generally typical for this unit. The top of Unit 1 is a high-permeability sandy gravel, from ground surface to about the 10-ft depth [645 to 635 ft above mean sea level (amsl)], that pinches out to the east. A laterally continuous, moderately high-permeability layer with a distinct high-resistivity geophysical response is found between the 20- and 50-ft depth (595 to 625 ft amsl) and occurs throughout the B-518 Area in an east-west direction. To the east, this sandy gravel thins to about 7 to 10 ft and increases in silt and clay content. The base of Unit 1 is characterized by a sandy gravel and gravelly sand that vary in clay content and thickness. The basal layer occurs in the eastern portion of the B-518 Area as a 3- to 10-ft-thick, high-permeability sandy gravel. To the west, near SIB-518-001 and SVB-518-202, there is a central lateral discontinuity, although the basal layer reappears further west near SIB-518-203 as a 15-ft-thick laterally continuous gravel with increased clay content near MW-211.

The second stratigraphic unit (Unit 2) occurs between depths of about 60 and 100 ft (550 to 590 ft amsl). Unit 2 consists predominantly of clayey silt and silty clay with lenses of high-permeability silty and gravelly sand. To the west, the high-permeability lenses are absent and the sequence consists mostly of silty clay (Fig. 4). Unit 2 has a moderately low gamma ray response, and its resistivity signature is marked by several elevated peaks reflecting silty and gravelly sand.

The third stratigraphic unit (Unit 3) is 5 to 10 ft of sandy gravel, gravelly sand, with lesser amounts of clayey silt and gravel, which occur between about 85 and 110 ft (540 to 565 ft amsl). A very high, sharp resistivity peak at the contact between Unit 2 and 3, and a low gamma ray response are the characteristic geophysical signatures for Unit 3 in the B-518 Area. This unit is

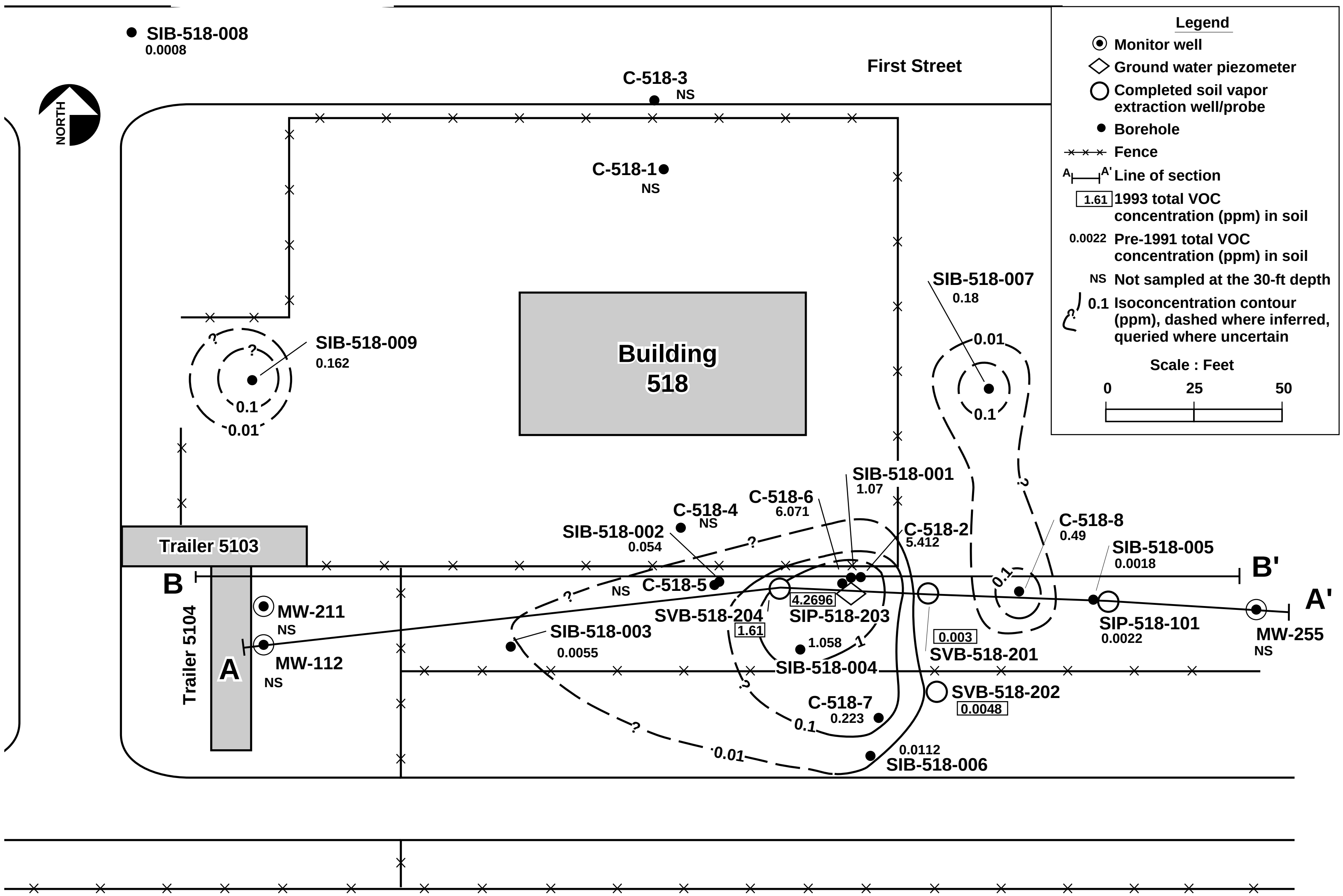

Figure 3. Borehole, monitor well, piezometer, and soil vapor extraction well/probe locations in the B-518 Area. Total VOC isoconcentration contours are for approximately 30-ft depth.

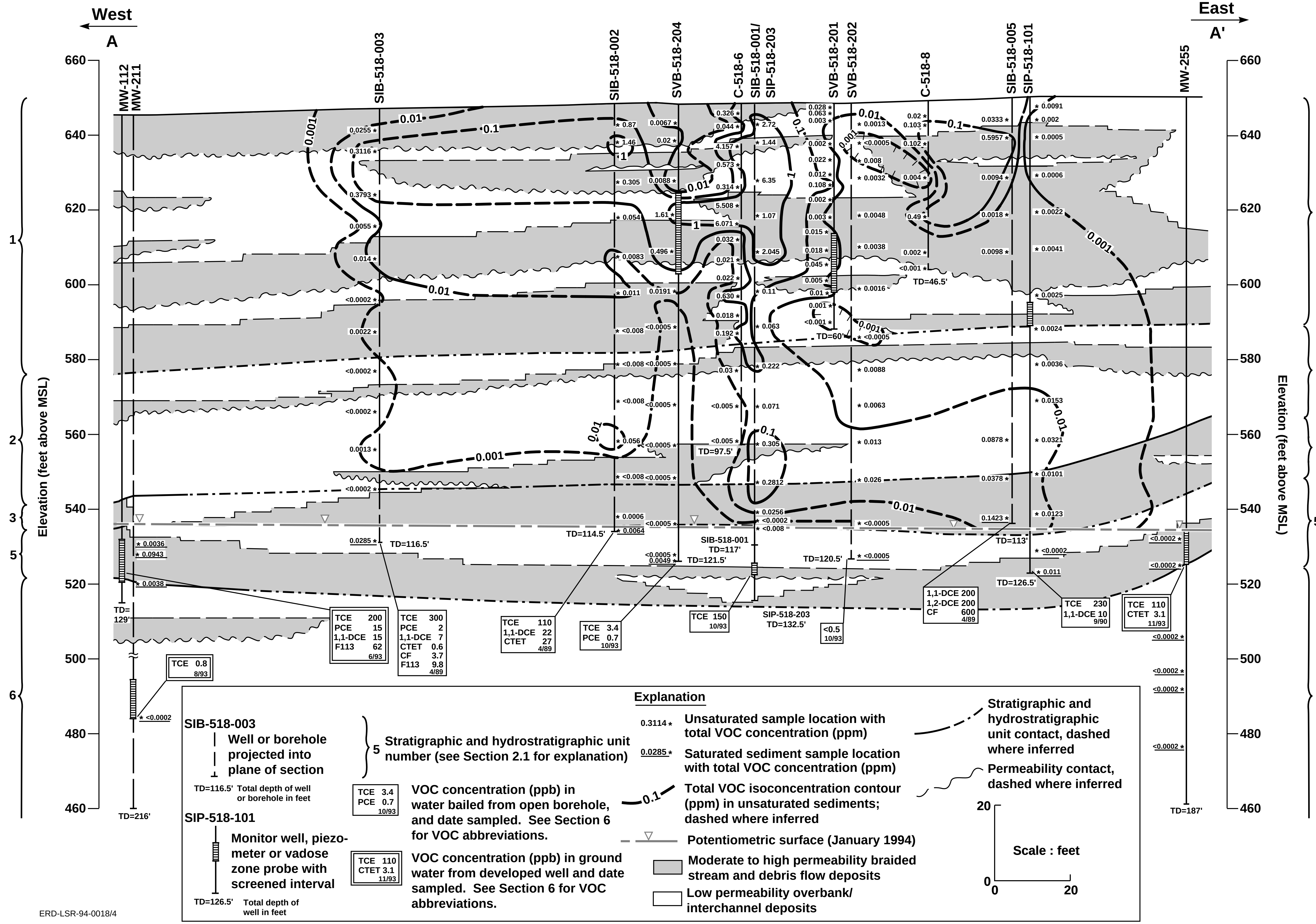

Figure 4. Hydrogeochemical cross section A-A' in the B-518 Area. For discussion of stratigraphic units and chemical data used in contouring, refer to Sections 2.1 and 2.2.

laterally continuous throughout the area, but thins to 5 ft to the west and exhibits an increased clay content.

The fourth stratigraphic unit (Unit 4) is absent both in the B-518 Area and in the southeastern TFE area to the north.

The fifth hydrostratigraphic unit (Unit 5), between the 100- and 140-ft depth (515 to 555 ft amsl), is the uppermost part of the Lower Member of the Livermore Formation. This unit is equivalent to the transition zone between the Upper Member of the Livermore Formation and the green and blue units below as described in the RI (Thorpe *et al.*, 1990). Unit 5 is 15 to 25 ft of clayey sand and silt underlain by laterally continuous gravelly silty sand and sandy gravel. Unit 5 exhibits an elevated gamma ray response and a subdued resistivity response in the fine-grained sediments, and a moderately high resistivity and a low gamma ray response in the basal sand/gravel. The potentiometric surface occurs within Unit 5, which is only partially saturated in the eastern part of the B-518 Area. Pumping test data for wells MW-112 and MW-255 (Fig. 3), which are completed in the basal sand/gravel layer, indicate lateral hydraulic communication within Unit 5 over a distance of about 300 ft.

The upper portion of the sixth hydrostratigraphic unit (Unit 6) consists of low permeability, light-green silty clay to clayey silt, with minor interbeds of clayey sand and gravel. This upper sequence in Unit 6 forms a regional confining layer throughout the Livermore Site area. This unit is equivalent to the green unit in the Lower Member of the Livermore Formation, as described in the RI (Thorpe *et al.*, 1990). The elevated gamma ray response of Unit 6 reflects the higher clay content within this unit.

2.2. VOC Distribution

B-518 was constructed in 1958 and has been used as a gas cylinder, solvent drum, and oil drum storage facility. The RI (Thorpe *et al.*, 1990) identified a total of five possible sites of hazardous material releases in this area, including several areas where leaking solvent drums may have drained onto unpaved ground.

Subsurface investigations near B-518 began in 1982 with the installation of eight boreholes (C-518-1 through C-518-8) to depths of approximately 59 ft (Carpenter, 1984) (Fig. 3). Chemical data collected from these boreholes (Appendix A) suggested that a release to the vadose zone had occurred in the area. In 1989, LLNL continued characterization near B-518. Soil vapor surveys to depths of 5 to 16 ft were conducted, and nine boreholes (SIB-518-001 through SIB-518-009) were drilled to the water table and chemical samples collected. Total VOC concentrations up to 6.3 parts per million (ppm) were detected in unsaturated soil samples, with the highest concentrations occurring between the surface and a depth of 50 ft (Fig. 4; Appendix A). Subsequently, two vapor extraction wells, one ground water piezometer, one air inlet well, and one vadose zone probe were drilled, sampled, and completed in the B-518 Area in 1990 and 1993.

The interpreted distribution of total VOCs in unsaturated sediment is shown for the 30-ft depth in Figure 3, and in sectional view in Figure 4. Borehole SIB-518-001 projects onto cross section A-A′ at about the same location as piezometer SIP-518-203 (Fig. 4). Because the vertical distribution of VOC concentrations is greater in SIB-518-001 than in SIP-518-203 (Appendix

A), unsaturated sediment VOC data from SIB-518-001 were used for contouring in Figure 4 as a conservative estimate of VOC mass. In addition, because of lower confidence in the 1984 and 1989 data, contours based on these data are shown approximately located with dashed lines.

The greatest lateral extent of total VOC concentrations exceeding 0.100 ppm is at about the 20-ft depth in cross section A-A′ (Fig. 4). However, the 30-ft depth was selected to represent the VOC distribution in plan view to show the greatest lateral extent of the 1 ppm contour (Fig. 3).

The unsaturated soil chemical data indicate that the highest concentrations of VOCs in the B-518 Area vadose zone occur above the 40-ft depth within Unit 1, with a maximum concentration of about 6.35 ppm at the 20-ft depth in borehole SIB-518-001 (Fig. 4; Appendix A). The distribution of VOCs with concentrations above 1 ppm in the upper 40 ft of the unsaturated zone appears to be about 25 ft wide in the northwest-southeast direction and about 40 ft long in the southwest-northeast direction (Figs. 3 and 4). Except for a total VOC concentration of 1.46 ppm at a depth of about 10 ft in SIB-518-002 (Fig. 4; Appendix A), the highest VOC concentrations are within a roughly cylindrical volume of sediments encompassing SIB-518-001. Up to 0.305 ppm total VOCs were also detected in Units 2 and 3 at about the 90-ft depth (Fig. 4) in well SIB-518-001. However, these elevated concentrations were not reported in samples from SIP-518-203, drilled about 5 ft south of SIB-518-001, and appear to be limited to a small area (Fig. 4).

Two small areas to the west and east of B-518 contain vadose zone total VOC soil concentrations over 0.1 ppm (Fig. 3). The total VOC concentrations in borehole SIB-518-009 to the west are highest at the 5.5-ft depth (0.258 ppm) and gradually decrease to the 0.0002-ppm detection limit about 10 ft above the potentiometric surface (Appendix A). Similarly, samples collected from boreholes SIB-518-007 and C-518-8 indicate concentrations exceeding 0.001 ppm in the upper 30 ft of the vadose zone (Figs. 3 and 4; Appendix A).

2.3. Treatability Test

To assist in the design of the B-518 vapor extraction wellfield, a treatability test was conducted from June 2 to 4, 1993, by extracting soil vapor from an existing vadose zone well in the B-518 Area. Vapor was extracted from SVE well SVB-518-201 (Fig. 3) using a vacuum pump. Two granular activated carbon (GAC) canisters connected in series were used to treat the extracted vapor. The treatability test setup and the June 2 and 3 test results were presented in RD3 (Berg *et al.*, 1994) and are included in Appendix B. The treatability test results, including June 4, 1993, data, are briefly summarized below.

The primary objectives of the June 1993 tests were to (1) evaluate whether SVE from existing wells can effectively remove VOCs from the B-518 subsurface, (2) determine the correlation between vapor flow and applied vacuum, and (3) estimate the potential VOC removal rate. The time-weighted average extracted vapor concentrations [in parts per million on a volume-per-volume basis ($ppm_{v/v}$)] for all three days are presented in Table 1. The volume of extracted vapor and VOC mass removed are presented in Table 2. VOC mass removal calculation methodology is presented in Appendix C. The TCE, PCE, and 1,1-dichloroethylene (1,1-DCE) concentrations remained fairly constant throughout the test, with a cumulative total of about 12 kilograms (kg) (2.3 gal) of VOCs removed during the three days (Table 2). The relationship between wellhead vacuum and flow rate is presented in Figure 5. When SVB-518-201 had a vacuum of 11.5 in. of mercury (Hg), a vadose zone probe 50 ft to the east (SIP-518-101) responded with a vacuum of 1.1 in. of water. Vapor extraction test data from well SVB-518-201 indicate that this well yielded about 40 $\pm$ 10 standard cubic feet per minute (scfm) under an applied 6 in. Hg vacuum. A vapor extraction system incorporating two to four vapor extraction wells completed in similar sediments should achieve 80 to 160 scfm total extraction flow under an applied vacuum of about 6 in. Hg. The total VOC concentration in the effluent from the GAC was less than 6 $ppm_{v/v}$.

Table 1. Average VOC concentrations extracted during the B-518 treatability test.

	Average concentration ($ppm_{v/v}$)		
Date	**TCE**	**PCE**	**1,1-DCE**
June 2, 1993	**370**	**210**	**120**
June 3, 1993	**420**	**220**	**150**
June 4, 1993	**410**	**300**	**160**

Table 2. Volume of extracted vapor and VOC mass removed during the B-518 treatability test.

	Volume extracted	Mass removed (kg)			
Date	**(m^3)**	**TCE**	**PCE**	**1,1-DCE**	**Total**
June 2, 1993	**1,400**	**2.8**	**2.0**	**0.7**	**5.5**
June 3, 1993	**450**	**1.0**	**0.7**	**0.3**	**2.0**
June 4, 1993	**900**	**2.0**	**1.9**	**0.6**	**4.5**
Total	**2,750**	**5.8**	**4.6**	**1.6**	**12**

The results of the SVE treatability test indicate that (1) vapor extraction from existing wells is an applicable and effective technique for removing VOCs from the vadose zone beneath the B-518 Area, and (2) GAC can successfully treat the expected VOC concentrations at the expected flow rates. However, a treatability test cannot accurately predict the effectiveness or duration of cleanup. Therefore, cleanup times were estimated using the two-dimensional Nonisothermal Unsaturated Flow and Transport (NUFT) code, as discussed in Section 2.4.

2.4. Flow and Transport Model

Two-dimensional simulations using the NUFT flow and transport code developed at LLNL (Nitao *et al.*, 1994) were used to help understand VOC transport in the sediments underlying the B-518 Area. As discussed in RD2 (Berg *et al.*, 1993), ground water in the B-518 Area contains VOCs above MCLs. The NUFT code was used to evaluate the incremental impact on ground water from VOCs in the vadose zone. The modeling results are presented in Appendix D and summarized below. Three-dimensional modeling will be used in the future to further evaluate vapor extraction system performance, extraction well configurations, and cleanup time estimates. Further details of this work, as well as future modeling, are planned for a separate technical report.

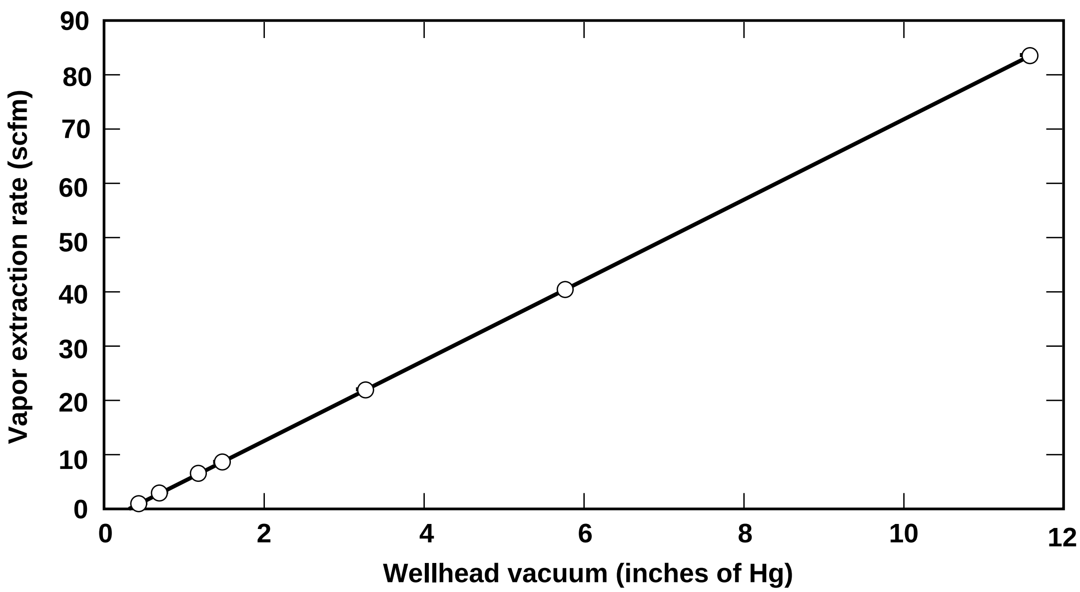

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Figure 5. Vapor flow rate versus extraction wellhead vacuum for the B-518 treatability test on June 3, 1993.

2.4.1. Phased Modeling Approach

A phased approach progressing from a simple to more complicated simulation scenarios was used to evaluate the wellfield design discussed in Section 2.5, and to estimate VOC changes in the subsurface over time. This phased approach evaluated two separate modeling cases. The first assumed homogeneous sediment properties based on site-specific averages, whereas the second used site-specific heterogeneous sediment properties. The homogeneous case is a useful benchmark in the early stages of remediation planning, when localized spatial and temporal issues are less important. The heterogeneous case is a better representation of the actual space- and time-dependent effects that govern SVE wellfield designs, performance monitoring plans, and cleanup time estimates. For each scenario, a no-action case and a number of simulations with continuous SVE for 1 to 12 years were performed.

A primary objective of the modeling is to estimate the extent and duration of SVE necessary to reduce VOC concentrations to residual levels that will not impact the ground water above MCLs. The MCL for TCE and PCE in ground water is 5 parts per billion (ppb), and the MCL for 1,1-DCE is 6 ppb. To obtain conservative estimates of cleanup times and the impacts of the VOCs on ground water, the effects of the most abundant VOC with the lowest MCL were modeled. Therefore, TCE was selected for simulation.

2.4.2. Conceptual Model of the B-518 Area

For this remedial design, the B-518 Area vadose zone was simulated as a two-dimensional area with vapor extraction well SVB-518-201 located in the center. Model parameters such as sediment type, saturation depth, and precipitation infiltration are presented in Appendix D.

Estimates of the TCE distribution into the vapor, aqueous, and solid phases were derived from selected sediment data (as described in Appendix D) and laboratory measurements of porosity and water saturation. The estimated TCE concentrations were incorporated onto east-west cross section B-B' (Figs. 3 and 6). The computer-interpolated cross section in Figure 6 shows a narrow zone of higher VOC concentrations around well SIB-518-001, similar to the interpretation in Figure 4.

2.4.3. Results

The total TCE mass in the vadose zone in the B-518 Area was initially estimated using the Dynamic Graphics, Inc. (DGI), Earth-Vision program, which interpolates VOC concentrations (Appendix D). This interpolation program estimated a total TCE mass of 22 kg. However, calibrating the model to the treatability test indicated that the total TCE mass may be up to five times greater (110 kg) in the homogeneous case, and up to two times greater (44 kg) in the heterogeneous case. Therefore, model calibration suggests that the total TCE mass may be more than the initial interpolation estimates from soil analytical data. This may be due to areas containing higher concentrations of TCE that were not intercepted by boreholes drilled during site characterization. Estimates using interpolation probably represent a lower bound of the total

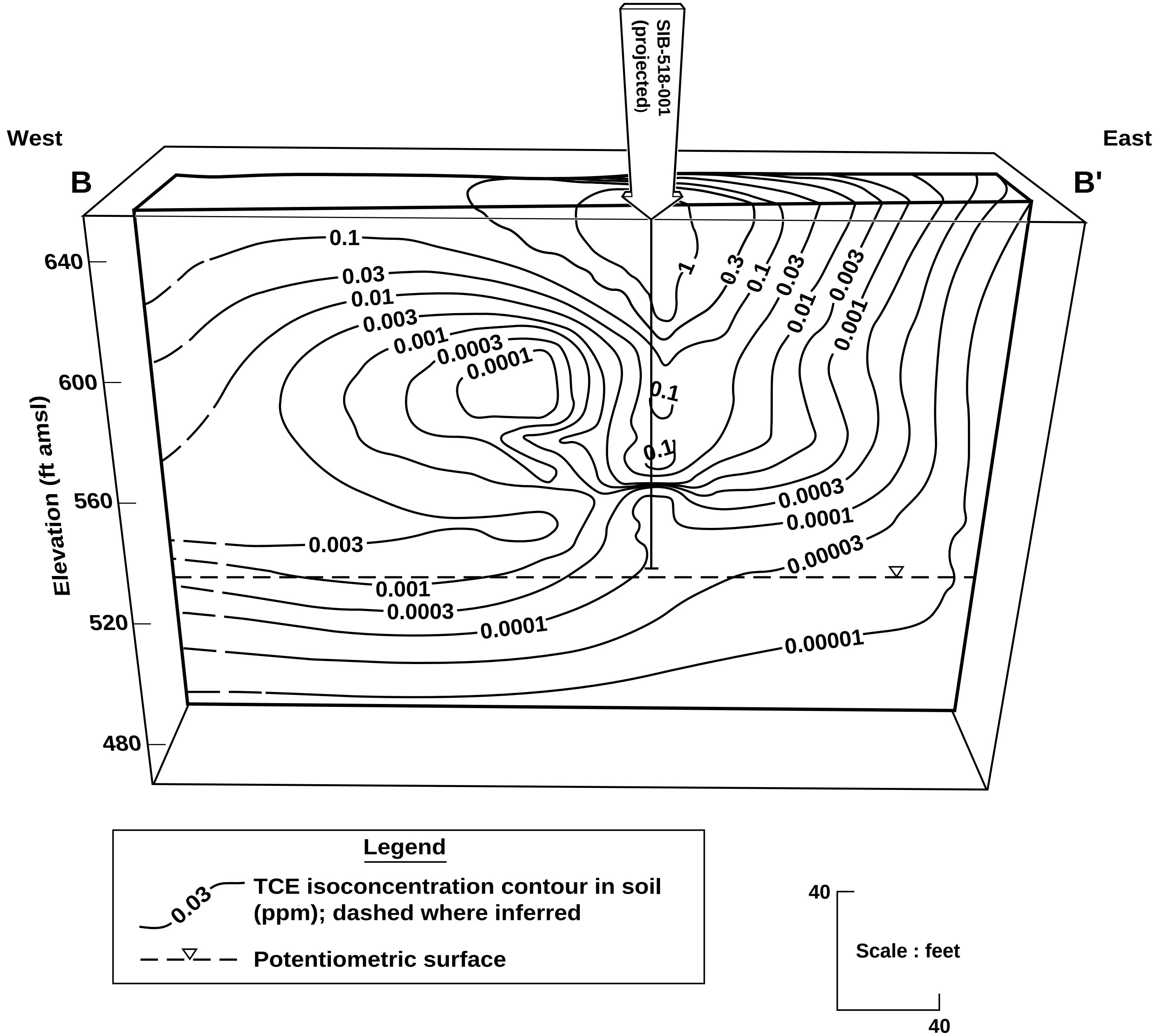

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Figure 6. Computer-interpolated TCE isoconcentration contours along an east-west cross section in the B-518 Area.

TCE mass in the vadose zone; thus, calibrating the model to the treatability test should provide more realistic estimates of TCE mass.

To assess the potential impacts to the ground water from residual VOC mass in the vadose zone, future VOC concentrations in the ground water were estimated by assuming (1) no remedial action, and (2) vapor extraction at well SVB-518-201. The no-remedial action scenario indicated that after several hundred years, TCE in the vadose zone may impact ground water to a maximum concentration of 280 ppb for both the homogeneous and heterogeneous cases. The simulations predicting the effects of remediation indicated that residual TCE in the vadose zone will not result in an impact to the ground water above 5 ppb after about 3 to 4 y of continuous extraction in the homogeneous case, and after about 5 to 6 y of continuous vapor extraction in the heterogeneous case (Appendix D). Ground water flow velocities of 1 m/y (Appendix G in Isherwood *et al.*, 1990) were assumed in both cases.

An approximate 5- to 6-y cleanup time is estimated based on the results of the heterogeneous model, in which it is estimated that a maximum of about 20 to 30 ppb TCE would remain in the sediments after 5 to 6 y of SVE (Appendix D). Although the exact zone of influence was not estimated, VOC concentrations in sediments within at least 50 m (160 ft) of the extraction well were reduced by extracting soil vapor from SVB-518-201 in both the homogeneous and heterogeneous cases. Future soil and/or soil vapor sampling and subsequent monitoring and modeling of field data will be used to verify that cleanup objectives have been achieved prior to ceasing remediation. As discussed in the ROD, the cleanup objectives will protect ground water from being impacted above MCLs. The process for determining when cleanup will be complete will be described in more detail in the forthcoming Compliance Monitoring Plan.

Figure 7 presents the estimated rate of TCE removal by SVE for both the homogeneous and heterogeneous models. Both cases indicate that greater than 75% of the TCE is removed in the first few years of vapor extraction and treatment. The mass removal rate drops off rapidly thereafter. The estimated cumulative volume of TCE removed approaches asymptotic levels of 17.5 gal (96.5 kg) for the homogeneous case, and 6.7 gal (36.8 kg) for the heterogeneous case. The modeling results support a system designed to treat 100 scfm of vapor, and estimate about a 5- to 6-y cleanup time.

2.5. Extraction Wells and Vadose Zone Probes

The B-518 Area vapor extraction well locations were selected by analyzing the local geology, the VOC distribution in unsaturated sediments, the treatability test data, and by using the flow and transport model to evaluate whether existing wells in the B-518 Area could effectively extract VOCs in soil vapor. The primary purpose of the SVE wells is to remove VOC mass by extracting vapor from areas with relatively high VOC concentrations. Ongoing monitoring and periodic model recalibration will be used to estimate when cleanup may be complete, and sediment and/or soil vapor samples will be collected to confirm that cleanup objectives have been met. Vapor extraction well and vadose zone probe locations and design are discussed in Sections 2.5.1 and 2.5.2, respectively.

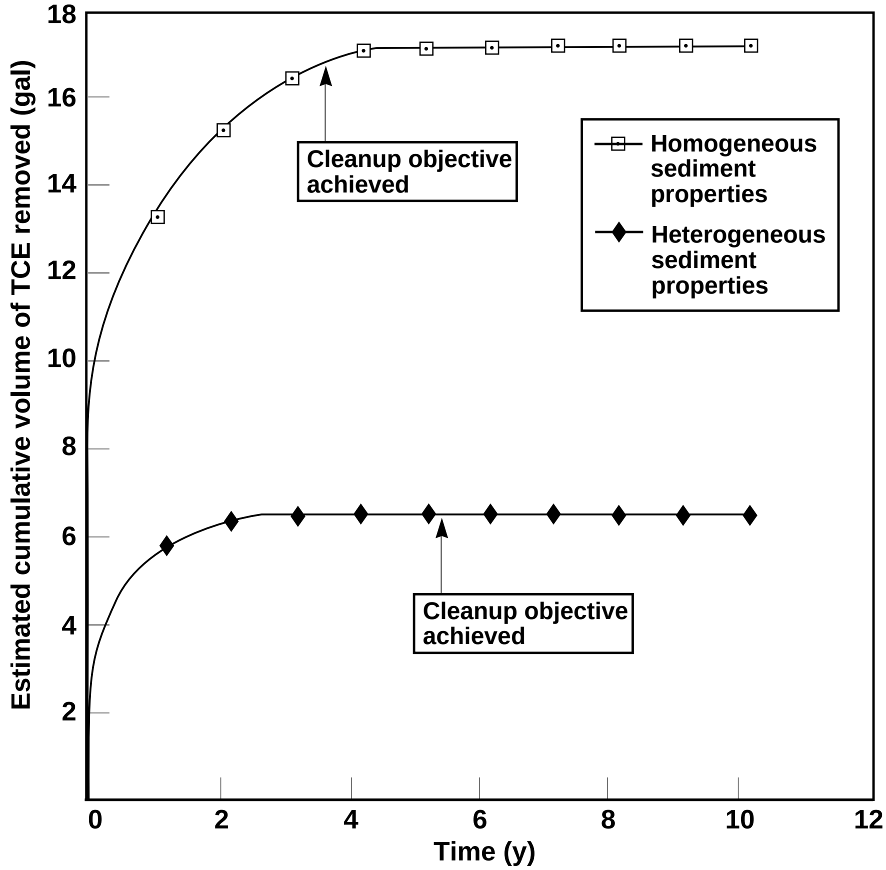

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Figure 7. Cumulative volume of TCE that may be removed by vapor extraction from the B-518 vadose zone over time at a vacuum pressure of 14 in. of Hg.

2.5.1. Vapor Extraction Well Location and Design

Three SVE wells are planned in the B-518 Area (Fig. 8). Two of the wells, SVB-518-204 (VEW-18-1A) and SVB-518-201 (VEW-18-1B), are currently installed in the area of highest VOC concentrations, and are screened from 24 to 46 ft and 34 to 50 ft, respectively (Fig. 4). The third vapor extraction well (VEW-18-2/3) will be installed to capture VOCs that were detected between about the 90- and 110-ft depth (Fig. 4). Design specifications for the B-518 vapor extraction wells are presented in Table 3.

In order to monitor changes in VOC soil vapor concentrations and vapor pressure during SVE in the B-518 Area, a SEAMIST instrumentation/sampling system is planned for installation in a new borehole located near SIP-518-203 (Fig. 8). The SEAMIST system is an air-pressure driven, impermeable, everting membrane that can carry soil vapor sampling instrumentation down an unlined borehole (Keller and Lowry, 1991). The membrane effectively lines the borehole like a continuous packer, thereby preventing fluid flow into the borehole. Once the membrane is emplaced, the SEAMIST system is completed by filling the interior of the membrane with dry sand to prevent borehole collapse. The SEAMIST system will be used to collect vapor pressure and soil vapor VOC data from various discrete depths. These data, which will be collected periodically during operation of the treatment facility, will be used to: (1) monitor cleanup of VOCs in both the shallow and deeper zones, (2) help optimize flow rates at the extraction wells, and (3) help determine when confirmatory sediment and/or soil vapor samples should be collected. These data will also be used to recalibrate the model discussed in Section 2.4.

Vapor extraction in the B-518 Area will begin at VEW-18-1A, VEW-18-1B, and VEW-18-2/3 as soon as piping to the treatment system is completed. Vapor flow rates and chemistry data will be collected to evaluate the effectiveness of the planned extraction system. The B-518 Vapor Treatment Facility and remedial wellfield have been designed for easy conversion between air inlet wells and vapor extraction wells, and the wellfield design can be modified to accomodate additional vapor extraction where necessary. To ensure that the SIB-518-007 area VOCs are within the zone of influence of a vapor extraction well, we plan to convert air inlet well VZP-18-1A into a SVE well for several months during treatment facility operation.

2.5.2. Vadose Zone Probe Location and Design

Vadose zone probes will be monitored to determine the influence of vapor extraction. The vadose zone probes will also act as air inlet wells to enhance vapor movement through the vadose zone.

As many as ten vadose zone probes may be installed if necessary in the B-518 Area, not including any of the planned vapor extraction wells that may also be used as vadose zone probes. The B-518 Area vadose zone probe locations shown in Figure 8 are based primarily on treatability test data. During the treatability test, a pressure response was observed at a radial distance of about 50 ft while vapor was being extracted from SVB-518-201 at about 110 scfm. Therefore, all vadose zone probes will be located within about 50 ft of the vapor extraction wells.

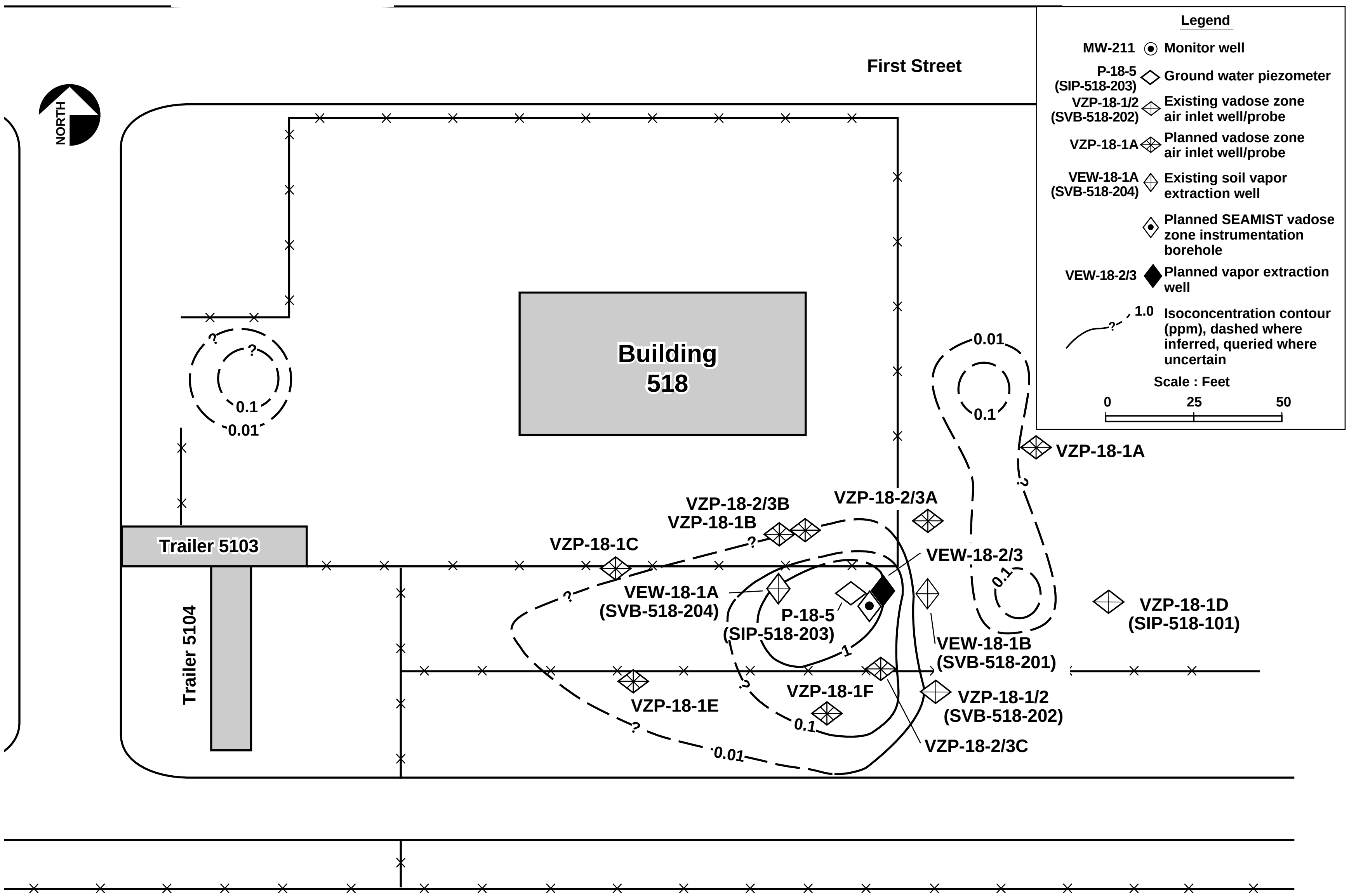

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Figure 8. Vapor extraction well and vadose zone air inlet well/probe locations and total VOCs in soil at the 30-ft depth in the B-518 Area.

Table 3. B-518 Vapor Treatment Facility SVE well specifications.

Well name	Extraction well name[a]	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval (ft)	Sand-pack interval (ft)	Stratigraphic unit[b]	Activation priority[c]
SVB-518-204	VEW-18-1A	5-Nov-93	121.5	46	24-46	22-46	First	1
SVB-518-201	VEW-18-1B	3-Mar-93	60	50	34-50	33-50	First	1
TBI	VEW-18-2/3	—	(112)	(110)	(90-110)	(89-110)	Second & third	2

Notes:

TBI=To be installed.

Estimates are shown in parentheses.

[a]Extraction well name indicates the stratigraphic unit monitored (i.e., VEW-18-1A is screened in the first unit). Letters following the unit designation indicate that multiple extraction wells are screened in the same stratigraphic unit (i.e., VEW-18-1A, VEW-18-1B, etc.). Figure 8 shows planned extraction well locations.

[b]Numbered consecutively downward from ground surface at each extraction location. A stratigraphic unit is defined as an unsaturated hydrostratigraphic unit, which is a sequence of sediments grouped together on the basis of hydraulic properties, and geologic, geophysical, and/or chemical data.

[c]Activation priority is the estimated order for connection to the treatment system. Activation priority is based on engineering design and cost, and the known or anticipated VOC concentrations in soil at the extraction locations.

Two of the ten vadose zone probes are currently installed, and four are planned for installation. Preliminary design specifications for the existing and planned probes are presented in Table 4.

Existing ground water piezometer SIP-518-203, completed in the uppermost saturated zone, will also be monitored quarterly for VOCs.

3. Remedial Design for the B-518 Vapor Treatment Facility

The B-518 Vapor Treatment Facility will treat VOC-bearing vapor extracted from the vadose zone in the B-518 Area. The principal VOCs in the B-518 Area are TCE, PCE, and 1,1-DCE. The treatment facility will consist primarily of a blower and three GAC adsorption canisters in series. GAC is considered the best available control technology (BACT) by the Bay Area Air Quality Management District (BAAQMD) for VOC removal from air (BAAQMD, 1992). The system will remove VOCs from extracted vapor before discharging it to the atmosphere in compliance with BAAQMD Authority to Construct discharge conditions, which require a 98.5% removal efficiency through the GAC and limits the effluent to 6 $ppm_{v/v}$ total VOCs (Appendix E).

LLNL ERD personnel conducted a pilot-scale vapor extraction test to determine design criteria for the B-518 Vapor Treatment Facility. The results of this test were presented in RD3 (Berg *et al.*, 1994) and summarized in Section 2.3 of this report. The results of the treatability test were used in the B-518 Vapor Treatment Facility design described in Section 3.1.

3.1. B-518 Vapor Treatment Facility Specifications, Design, Controls, and Safeguards

The specifications, design, controls, and safeguards for the B-518 Vapor Treatment Facility and its associated piping are described in Sections 3.1.1 and 3.1.2.

3.1.1. Specifications and Design

The B-518 vapor extraction system is designed to treat 150 scfm. However, the treatment facility should effectively remove and treat VOCs even if only 100 scfm is achieved; the higher flow capacity will allow future system expansion, if necessary. The system will be automated for unmanned operation. Design average VOC influent concentrations obtained from the treatability test are shown in Table 5.

Table 5. B-518 Vapor Treatment Facility design influent concentrations (June 1993 data).

	Concentration ($ppm_{v/v}$)	
Constituent	**Average influent**	**Effluent discharge requirements**
TCE	**400**	**6[a]**
PCE	**240**	**6[a]**
1,1-DCE	**140**	**6[a]**

[a]There are no individual discharge limits for these VOCs; they are included in the 6 $ppm_{v/v}$ total VOC limit.

Table 4. B-518 Vapor Treatment Facility vadose zone probe specifications.

Well name	Vadose zone probe name[a]	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval (ft)	Sand-pack interval (ft)	Stratigraphic unit[b]	Activation priority[c]
TBI	VZP-18-1A	—	(62)	(62)	(20-60)	(19-61)	First	6
TBI	VZP-18-1B	—	(62)	(62)	(20-60)	(19-61)	First	4
TBI	VZP-18-1C	—	(62)	(62)	(20-60)	(19-61)	First	3
SIP-518-101	VZP-18-1D	20-Sep-90	125	61	55-61	51-61	First	1
TBI	VZP-18-1E	—	(62)	(62)	(20-60)	(19-61)	First	2
TBI	VZP-18-1F	—	(62)	(62)	(20-60)	(19-61)	First	5
SVB-518-202	VZP-18-1/2	3-Nov-93	120.6	74.5	19-73.5	18-74.5	First & second	1
TBI	VZP-18-2/3A	—	(110)	(110)	(90-110)	(88-110)	Second & third	7
TBI	VZP-18-2/3B	—	(110)	(110)	(90-110)	(88-110)	Second & third	8
TBI	VZP-18-2/3C	—	(110)	(110)	(90-110)	(88-110)	Second & third	9
SIP-518-203[d]	P-18-5	21-Oct-93	132.5	127	121-127	119-128	Fifth	1

Notes:

TBI = To be installed.

Estimates are shown in parentheses.

[a]Vadose zone probe names indicate the stratigraphic unit monitored (i.e., VZP-18-1A is screened in the first unit). Letters following the unit designation indicate that multiple probes are screened in that unit. Figure 8 shows planned probe locations.

[b]Numbered consecutively downward from ground surface at each extraction location. A stratigraphic unit is defined as an unsaturated hydrostratigraphic unit, which is a sequence of sediments grouped together on the basis of hydraulic properties, and geologic, geophysical, and/or chemical data.

[c]Vadose zone probe activiation is prioritized according to the activation of the associated extraction well(s).

[d]SIP-518-203 is a ground water piezometer.

The specifications and design for the B-518 Vapor Treatment Facility are presented below. The equipment specifications are presented in Table 6. A P&ID and a location plan are presented on Plate 1*.

Table 6. B-518 Vapor Treatment Facility equipment specifications.

Equipment	Specification
Wellhead demisters	**4-in. flanged ends, 19-in. long, 12-in.-diameter enlarged section with Koch Engineering Co. demisting mesh, or equivalent**
Vacuum and pressure gauges	**Dwyer differential pressure gauges, or equivalent. Depending on flow rate these will range from 0 to 5 in. mercury (Hg) and 0 to 20 in. Hg**
Temperature gauges	**Marshall Instruments, Inc., industrial adjustable-angle thermometer, or equivalent**
Air flow sensors	**Annubar averaging Pitot-tube differential pressure flow sensor, 2 in. for individual wells, and 4 in. for the manifold, or equivalent**
Combined flow demister	**H2 Oil Recovery Equipment, Inc., air/water separator with high-level shutdown, or equivalent**
Heat exchanger	**Chiller Manufacturing Co., 20,000 British Thermal Units per hour air-to-air heat exchanger, or equivalent**
GAC	**Carbtrol Model G-2 170 lb carbon, 300 standard cubic feet per minute (scfm) nominal flow rating, 8 pounds per square in. (psi) vacuum rating, or equivalent**
Vapor extraction blower	**Sutorbilt California Legend 3L APU Model II positive displacement vacuum blower powered by a 10 horsepower, 460-volt alternating current, 3-phase electric motor, 115 scfm at 10-in. Hg vacuum (approximately 5 psi) equipped with air intake piping and silencer, or equivalent**

Extracted vapor will be routed from each extraction well to a common manifold. The combined flow will be routed through a demister, a heat exchanger, three GAC canisters in series, the blower, and again through the heat exchanger before atmospheric discharge.

GAC adsorbs most efficiently at 40% relative humidity (RH) and a temperature below 100°F. Extracted vapor will contain entrained moisture droplets and will be saturated with water vapor (100% RH) at about 60°F (the subsurface temperature). The demister will remove most entrained droplets, although vapor will remain saturated with water. Therefore, the treatment facility design uses the heat produced within the blower to warm extracted vapor to reduce the RH without exceeding the optimal temperature range of the GAC. Bypass piping for both the extracted vapor being heated in the heat exchanger, and the blower effluent providing heat to the heat exchanger (Plate 1), allow adjustment of the extracted vapor stream to the optimal temperature entering the GAC.

DOE/LLNL plan to install the B-518 Vapor Treatment Facility outdoors on an 8- x 16-ft, 6-in.-thick reinforced concrete pad [3,000 pounds per square inch (psi) rating] southeast of B-

* Plate 1 is located in a pocket inside the back cover of this report.

518 (Plate 1). The blower will be enclosed in a weather- and soundproof box. All other equipment is designed to withstand outdoor conditions.

Each extraction well will be equipped with a wellhead demister. The demister consists of a 19-in.-long, flanged 12-in.-diameter duct that adapts to the 4-in. extraction well casing. Within the large-diameter section is a demister mesh. The mesh is a stainless steel sponge-like material that allows fine water droplets or mist to coalesce into larger droplets. Because demisters rarely remove all entrained moisture, these wellhead demisters are intended to supplement the combined stream demister described below.

Vapor extraction piping from the wellhead demisters will be equipped with quick-connect couplers. Extraction wells will be connected to the treatment facility by 40- to 60-ft-long, 2-in.-diameter flexible polyvinyl chloride (PVC) hoses. These hoses can be moved easily to allow connection to any extraction well. The hoses can withstand 15 psi (30 in. Hg) vacuum, well above the expected maximum vacuum of about 5 psi (10 in. Hg).

Extraction hoses will be connected to a common vapor extraction manifold. The manifold will accommodate four extraction hoses for additional extraction wells, if needed. Each manifold connection will include a 5-ft-long, 2-in.-diameter straight section of rigid Schedule 80 chlorinated PVC with a fitting for an averaging Pitot-tube differential pressure flow sensor. Additionally, each connection will be equipped with a separate sampling port, temperature and vacuum gauges, and a manually adjusted flow-control ball valve. The ball valve will allow flow reduction from high-flowing wells, which will increase the applied vacuum in the manifold and lower flowing wells.

The 4-in.-diameter PVC common manifold will have an additional vacuum gauge to measure manifold vacuum and evaluate the vacuum increase across each ball valve. Piping from the manifold will be routed to a cyclone demister. This demisting stage will provide additional moisture removal from the extracted vapor stream. Water accumulated in the cyclone demister storage tank will be transported to one of the Livermore Site ground water treatment facilities for treatment. We anticipate that less than 5 gal of water will accumulate in the cyclone demister per day. Temperature and pressure gauges installed after the demister will provide information about relative flow rates and vacuum efficiency. From the demister, extracted vapor will be routed to the cool side of an air-to-air heat exchanger (20,000 British Thermal Units per hour). To reduce the RH to about 40%, extracted air will be warmed in the heat exchanger from about 60°F to 100°F.

The warmed extracted air stream will be routed from the heat exchanger to three 170-lb GAC canisters connected in series with 4-in.-diameter flexible PVC hose and quick-connect fittings. Each vessel will be equipped with influent and effluent vacuum gauges, sampling ports, and a temperature gauge. The instrumentation will provide information about relative flow rate and vacuum efficiency. A flow rate of 100 scfm from the wells will cause less than 3 in. Hg head loss through the piping, carbon canisters, and components, which will result in a sufficient applied vacuum of about 5 to 7 in. Hg at the wellhead. The flexible connectors will allow easy repositioning of the GAC canisters when they are removed for regeneration or disposal. Sampling ports will enable VOC monitoring to determine when contaminant breakthrough occurs.

Treated vapor leaving the third GAC canister will be connected to the blower with 4-in.-diameter flexible PVC hose connected to rigid PVC pipe. The 4-in. averaging Pitot-tube differential pressure flow sensor will measure the combined vapor flow into the vapor extraction blower. Vacuum and temperature gauges installed in this pipe will provide information about relative flow rate and vacuum efficiency. An air intake valve and pipe will be used if the vapor flow rate from the extraction wells is too low to adequately cool the blower.

The blower for the B-518 Vapor Treatment Facility will be a Sutorbilt California Legend 3L APU Model II positive displacement vacuum blower, or equivalent, powered by a 10-horsepower, 460-volt, 3-phase electric motor. This model blower is rated at 115 scfm at 10 in. Hg vacuum.

Piping downstream from the blower will be equipped with an over-pressure relief valve and pressure, temperature, and flow instrumentation. Piping material, downstream from the blower, will be selected to withstand temperatures as warm as 140° to 160°F, depending on the applied vacuum and flow rates. This heated air stream will be routed to the air-to-air heat exchanger to warm the extracted air stream. An air bypass will allow precise adjustment of the amount of hot air entering the heat exchanger, should reduction be necessary. The treated effluent will be discharged to the atmosphere. Carbon filter effluent will be analyzed five times per week.

3.1.2. Controls and Safeguards

The B-518 Vapor Treatment Facility is designed to be fail-safe and will be equipped with an interlock control system. If one of the components listed below malfunctions, the extraction blower will automatically shut down. The operator must determine and correct the problem before the system can be manually restarted.

A system-wide shutdown would be initiated by the following hard-wired interlocks:

- High water level in the demister.
- High air temperature entering the GAC.
- High pressure downstream of the blowers.
- High temperature downstream of the blowers.
- Loss of power to the instrumentation.

All equipment will be inspected during normal work hours each day of system operation.

3.2. Construction and Startup Schedule and Cost Estimates

3.2.1. Schedule

Technology evaluation and conceptual design for the B-518 Vapor Treatment Facility were conducted by ERD in January 1994. LLNL Plant Engineering will complete the site design that will be used for construction. The treatment system will be purchased through the LLNL procurement system. Construction is scheduled to begin in May 1995, and the system is scheduled for operation by September 29, 1995 (Table 7).

Table 7. B-518 Vapor Treatment Facility design and construction schedule.

Item	Start	End
B-518 Vapor Treatment Facility design	**1/94**	**12/94**
B-518 Vapor Treatment Facility construction	**5/95**	**8/95**
B-518 Vapor Treatment Facility activation	**8/95**	**9/29/95**

3.2.2. Cost Estimates

The estimated costs for design, construction, and O&M of the B-518 Vapor Treatment Facility are shown in Table 8. The piping and power cost in Table 8 includes design, construction, piping, and power. The process equipment cost includes the blower, demisters, instrumentation, GAC canisters, heat exchanger, and additional hardware. The estimated total design and construction cost of this facility is about $110,000.

Estimated O&M costs include all labor and material costs associated with operating the facility. The costs in Table 8 include the O&M cost during the estimated 6 y to reach cleanup goals (Section 2.4).

4. Remedial Action Workplan

The Remedial Action Workplan for the B-518 Vapor Treatment Facility includes QA/QC Plans and HASPs for construction, operation, and maintenance. Included also are monitoring and reporting programs, requirements for onsite storage and offsite shipment of hazardous waste, and procedures for facility and well closure. As discussed in the RAIP (Dresen *et al.*, 1993), DOE/LLNL have updated the Community Relations Plan (CRP) for the post-ROD period. The Revised CRP was issued in July 1993 (Anderson *et al.*, 1993).

4.1. Quality Assurance/Quality Control and Health and Safety Plans

The QA/QC Plan and the HASP for construction are applicable to all treatment facilities and were presented as Appendices B and C of RD1, respectively (Boegel *et al*., 1993).

The QA/QC Plans for O&M of the B-518 Vapor Treatment Facility are presented in Appendix F. These plans describe the organizational structure, responsibilities, and authority for O&M QA/QC, and the objectives, quality goals, and QA levels for O&M of the B-518 Vapor Treatment Facility. Appendix G contains the HASPs for O&M of the B-518 Vapor Treatment Facility. These plans present analyses of hazards, and hazard control measures and training requirements for the treatment facility O&M, and emergency safety procedures.

4.2. Monitoring and Reporting

The B-518 Vapor Treatment Facility self-monitoring program will satisfy the BAAQMD discharge requirements of 6 $ppm_{v/v}$ total VOCs. Effluent air will be sampled downstream of the GAC five times per week (Appendix E), and the samples will be analyzed using an organic vapor analyzer/flame ionization detector (OVA/FID). The FID uses a flame to ionize molecules in the

Table 8. B-518 Vapor Treatment Facility cost summary.

Item	Cost[a]	Annual O&M[a]	6-y cleanup O&M[a]
B-518 Vapor Treatment Facility (including design, construction, piping, and power)	**$50,000**	—	—
Process equipment	**22,000**	—	—
Activation cost	**20,000**		
9.7% MPC[b]	**3,100**	—	—
Subtotal	***95,100***	—	—
B-518 Vapor Treatment Facility Operation & Maintenance:			
Labor:			
ERD personnel[c]	—	**$378,000**	**$2,268,000**
LLNL Hazardous Waste Management	—	**12,000**	**72,000**
Plant support	—	**18,000**	**108,000**
Subtotal	—	***408,000***	**2,448,000**
Materials:			
GAC	—	**3,000**	**18,000**
Blower	—	**100**	**600**
Miscellaneous piping	—	**1,000**	**6,000**
Miscellaneous electronics	—	**2,000**	**12,000**
Sample analyses	—	**24,000**	**144,000**
9.7% MPC[b]	—	**2,920**	**17,518**
Subtotal	—	***33,020***	***198,118***
13% G&A/LDRD[d] charge	**12,363**	**57,333**	**343,995**
Total	**$107,463**	**$498,353**	**$2,990,113**

[a]Estimated cost is in Fiscal Year 94 dollars and does not include yearly escalation.

[b]Material Procurement Charge.

[c]ERD personnel labor estimates include hydrogeologist, chemist, engineer, technician, and analyst time to meet the requirements in the ROD and milestones in the RAIP. The estimated 6-y cleanup cost reflects time for these staff to maintain and improve treatment systems, effectively manage the wellfield as conditions change over the life of the cleanup, and evaluate and potentially implement new cleanup technologies as they are developed.

[d]General and Administrative/Laboratory Directed Research and Development cost.

vapor sample and measure the organic constituents within the vapor. LLNL uses OVAs equipped with FIDs. These instruments can detect compounds within a concentration range of 1 to 100,000 $ppm_{V/V}$. To determine the amount of methane in the discharge, samples will be taken with and without a carbon filter tip on the OVA/FID (Appendix E).

Influent and effluent VOC concentrations from each GAC canister will be measured with an OVA/FID to monitor GAC loading. A calibration adjustment will be made after each startup of the OVA/FID, according to manufacturers' specifications. GAC consumption is estimated to be as high as one canister per day immediately after system startup. As clean air dilutes VOC-saturated vapor in the subsurface, and as VOCs are removed, VOC concentrations in extracted vapor are expected to decline, and GAC consumption will drop accordingly. VOC concentrations in the GAC will be monitored, and GAC canisters will be replaced as necessary. When the vapor extraction system is initially started, a source test will be conducted for 3 consecutive days as required by BAAQMD (Appendix E). Field measurements using an OVA/FID will be performed and a sample will be collected simultaneously for analysis at an onsite laboratory. Results of the laboratory analysis will be available within a few hours, and will be used to verify field measurements.

The GAC in a canister will be considered saturated when the effluent vapor has approximately the same VOC concentration as the influent. The first GAC canister can reach saturation without VOC discharge to the atmosphere because the second and third GAC canisters will continue to adsorb the VOCs. Therefore, even with initial high GAC consumption, the second and third canisters ensure protection from discharge to the atmosphere. When the first GAC canister becomes saturated, the system will be shut down, the saturated canister will be removed, and the second and third canisters will be moved into the first and second positions, respectively. A new GAC canister will be placed in the third position.

In addition to the B-518 Vapor Treatment Facility monitoring, associated vapor extraction wells and probes will be sampled according to the schedule in Table 9.

Table 9. Sampling schedule for vapor extraction wells and vadose zone probes near the B-518 Vapor Treatment Facility.

Well identification	Media	Analyses	Sampling frequency
P-18-5 (SIP-518-203)	Water	601[a]	Q[b]
VEW-18-1A (SVB-518-204)	Vapor	OVA/FID[c]	Q[b, d]
VEW-18-1B (SVB-518-201)	Vapor	OVA/FID[c]	Q[b, d]
VZP-18-1/2 (SVB-518-202)	Vapor	OVA/FID[c]	Q[b]
VZP-18-1D (SVB-518-101)	Vapor	OVA/FID[c]	Q[b]

[a]601 = EPA Method 601 for halogenated VOCs.

[b]Q=Quarterly, planned in March, June, September, December.

[c]OVA/FID = organic vapor analyzer/flame ionization detector.

[d]Weekly monitoring will be conducted for the first 3 months of initial operation. At that point, monitoring will be conducted quarterly.

QA/QC procedures for collection, analysis, and documentation of samples are included in the LLNL Quality Assurance Project Plan (Rice, 1989), which was prepared according to EPA guidance and was approved by EPA. The procedures for vapor sample collection at the B-518 Vapor Treatment Facility are presented in Appendix H. In addition, general procedures for collection, analysis, and documentation of samples are described in LLNL Standard Operating Procedures (SOPs) (Rice *et al.*, 1990) Nos.: 4.1, General Instructions for Field Personnel; 4.2, Sample Control and Documentation; 4.3, Sample Containers and Preservation; 4.4, Guide to Handling, Packaging, and Shipping of Samples; 4.6, QA/QC Requirements for Data Generated by Analytical Laboratories; and 4.8, Calibration and Maintenance of Field Instruments Used in Measuring Parameters of Surface and Ground Water and Soils.

A Compliance Monitoring Plan will be prepared in Fiscal Years 95-96 that will describe the data types and interpretive methods to be used for the duration of the cleanup. Until then, DOE/LLNL will report on the progress of the B-518 Vapor Treatment Facility in the *LLNL Ground Water Project Quarterly Progress Reports* (McConachie, 1993).

4.3. Requirements for Onsite Storage and Offsite Shipment of Hazardous Waste

GAC containing sorbed VOCs will be shipped offsite for regeneration or disposal, and will be managed as hazardous waste, if appropriate. LLNL can temporarily store hazardous waste onsite for up to 90 days. Shipment and disposal are in accordance with Department of Transportation 49 Code of Federal Regulations (CFR) and EPA 40 CFR, respectively. Additionally, waste shipments are made according to California Code of Regulations, Title 22 requirements. The spent GAC will be packaged and labeled for shipment by LLNL's Hazardous Waste Management Division (HWMD). HWMD operates under Interim Status and has submitted a Resource Conservation and Recovery Act (RCRA) Part B permit application to the DTSC (California is a fully RCRA-authorized State). Once packaged, the GAC will be shipped to one of several RCRA-permitted facilities for regeneration or disposal.

4.4. Requirements for Closeout

Ongoing field monitoring and periodic model recalibration will be used to estimate when cleanup will be complete. Sediment and/or soil vapor samples will be collected to confirm that cleanup objectives have been met. The process for determining when the B-518 cleanup will be complete will be described in the forthcoming Compliance Monitoring Plan.

When the vadose zone cleanup at the B-518 Area is complete, all treatment system hardware will be decontaminated, dismantled, and salvaged or used at other locations at the Livermore Site. The system piping, demisters, and instruments will be flushed by opening the vapor manifold to ambient air while operating the system. Because the GAC canisters precede the blower and much of the system piping, minimal decontamination, if any, will be necessary. An OVA/FID will be used to evaluate whether equipment such as the blower, demister, and heat exchanger contain residual VOCs.

Vapor extraction wells will be sealed by pressure grouting using a grout mixture of 98% Portland cement and 2% bentonite powder by weight, as described in LLNL SOP 1.7 (Rice *et al.*, 1990). Cement grout should extend to a depth of 2 to 3 ft below grade. Wellhead abandonment will include removal of any protective covers, instruments, concrete pads, etc., and the upper 2 to 3 ft will be filled with low-permeability soil or asphalt to restore grade.

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5.2. References for LLNL Facilities Standards, Specifications, and Guide Documents

5.2.1. General

Designs, construction drawings, and specifications will conform to and comply with the applicable requirements of the latest adopted edition of the references listed below, which are considered minimum requirements.

5.2.2. Regulations

<u>U.S. Department of Energy (DOE)</u>

DOE 5480.7A Fire Protection Program

DOE 6430.1A General Design Criteria

<u>Code of Federal Regulations (CFR)</u>

10 CFR 435	Energy Conservation Standards
29 CFR 1910	Occupational Safety and Health Standards (OSHA)
29 CFR 1910.7	Definitions and Requirements for a Nationally Recognized Testing Laboratory (NRTL)
47 CFR 15	Telecommunication (FCC Rules, Part 15)

<u>State of California Department of Labor (DOL)</u>

DOL Labor Code	Division 5—Safety in Employment; Chapter 9—Miscellaneous Labor Provisions

<u>California Code of Regulations (CCR)</u>

CCR Title 8	Industrial Relations; Chapter 4, Subchapter 6
CCR Title 20	Public Utilities; Chapter 53—Energy Conservation in New Building Construction

<u>University of California, Lawrence Livermore National Laboratory (UCRL)</u>

UCRL 15910	Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards
UCRL 15714	Suspended Ceiling System Survey and Seismic Bracing Recommendations

5.2.3. Codes

American Concrete Institute (ACI)

ACI 318 Building Code Requirements for Reinforced Concrete

American Institute of Steel Construction (AISC)

AISC Steel Construction Manual (Allowable Stress Design)

American National Standards Institute (ANSI)

ANSI A58.1 Building Code Requirements for Minimum Design Loads for Buildings and Other Structures

American Welding Society (AWS)

AWS D 1.1 Structural Welding Code—Steel

International Conference of Building Officials (ICBO)

ICBO UBC Uniform Building Code

ICBO UMC Uniform Mechanical Code

ICBO UPC Uniform Plumbing Code

National Fire Protection Association (NFPA)

NFPA 70 National Electrical Code

NFPA 90A Installation of Air Conditioning and Ventilating Conditioning Systems

5.2.4. Standards

American Concrete Institute (ACI)

ACI 347 Recommended Practice for Concrete Form Work

American Society for Testing and Materials (ASTM)

American Water Works Association (AWWA)

Construction Specifications Institute (CSI)

National Electric Manufacturers Association (NEMA)

Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACCNA)

5.2.5. LLNL Manuals and Reports

M-010 LLNL Health and Safety Manual

LLNL Site Development and Facilities Utilization Plan

LLNL Landscape Master Plan and Design Guidelines

6. Acronyms and Abbreviations

1,1-DCE	1,1-dichloroethylene
A	ampere
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
amsl	above mean sea level
ANSI	American National Standards Institute
ARAR	Applicable or Relevant and Appropriate Requirement
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Water Works Association
B-518	Building 518
BAAQMD	Bay Area Air Quality Management District
BACT	Best Available Control Technology
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	chloroform
CFR	Code of Federal Regulations
CI	Construction Inspector
CM	Construction Manager
CPR	cardiopulmonary resuscitation
CRP	Community Relations Plan
CSI	Construction Specifications Institute
CTET	carbon tetrachloride
dB	decibel
DOE	U.S. Department of Energy
DOL	Department of Labor
DTSC	California Department of Toxic Substances Control
EE	Electronic Engineering
EPA	U.S. Environmental Protection Agency
ERD	Environmental Restoration Division
ES&H	Environmental Safety & Health
°F	degree(s) Fahrenheit
F113	trichlorotrifluoroethane (Freon 113)
FCC	Federal Communication Commission
FFA	Federal Facility Agreement
FHC	fuel hydrocarbon
FID	flame ionization detector
FS	Feasibility Study
ft	foot, feet
GAC	granular activated carbon
gal	gallon(s)
G&A/LDRD	General and Administrative/Laboratory Directed Research and Development
h	hour(s)
HASP	Health and Safety Plan
Hg	mercury
HWM	Hazardous Waste Management

HWMD	Hazardous Waste Management Division
ICBO	International Conference of Building Officials
in.	inch(es)
K	Kelvin
kg	kilogram
lb	pound
LLNL	Lawrence Livermore National Laboratory
LSRSL	Livermore Site Restoration Section Leader
m	meter(s)
MCL	Maximum Contaminant Level
ME	Mechanical Engineering
M&I	materials and items
MPC	Material Procurement Charge
MSL	mean sea level
M&TE	measuring and test equipment
NEMA	National Electric Manufacturers Association
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NQA	National Quality Assurance
NRTL	Nationally Recognized Testing Laboratory
NUFT	Nonisothermal Unsaturated Flow and Transport
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
OTL	Operations Team Leader
OVA	organic vapor analyzer
PCE	perchloroethylene
PE	Plant Engineering
PEPE	Plant Engineering Project Engineer
PEPM	Plant Engineering Project Manager
P&ID	piping and instrument diagram
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QAM	Quality Assurance Manager
QC	quality control
RAIP	Remedial Action Implementation Plan
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RD1	Remedial Design Report No. 1
RD2	Remedial Design Report No. 2
RD3	Remedial Design Report No. 3
RE	Remediation Engineer
RH	relative humidity
RI	Remedial Investigation
ROD	Record of Decision
RWQCB	California Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
scfm	standard cubic feet per minute
SMACCNA	Sheet Metal and Air Conditioning Contractors National Association, Inc.

SOP	Standard Operating Procedure
SSF	soil surface flux
SVE	soil vapor extraction
TBI	to be installed
TCE	trichloroethylene
TFD	Treatment Facility D
TFE	Treatment Facility E
TFF	Treatment Facility F
TWA	time-weighted average
UBC	Uniform Building Code
UCRL	University of California, Radiation Laboratory
VOC	volatile organic compound
v/v	volume per volume basis
y	year(s)

7. Acknowledgments

The technical editors and authors would like to recognize the contributions to this report of the following people:

W. McConachie, LLNL Environmental Restoration Division Leader, provided overall direction and quality assurance.

A. Copeland, LLNL Environmental Restoration Deputy Division Leader, provided quality assurance and technical guidance.

R. Blake of LLNL served as the Remedial Design Task Leader and provided quality assurance for the B-518 Area stratigraphic unit interpretation.

R. Devany of Weiss Associates provided technical support and quality assurance for the B-518 Vapor Treatment Facility wellfield design and hydrostratigraphy.

T. Vogele of Weiss Associates provided technical support for the NUFT code.

J. Loftis assisted with the B-518 Treatment Facility treatability study.

M. Brazell of LLNL provided Appendix A.

A. Ballard of LLNL/TID and M. Meamber of Jobs Plus/TID prepared the graphics.

B. Justin and B. Staley of LLNL/TID provided publication services.

H. Sherman of LLNL/TID provided editorial support.

N. Prentice of LLNL and L. Cohan of KMI provided clerical support.

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Appendix A*

Soil and Ground Water Analytical Results

***NOTICE: Appendix A exists only in hard copy. Hard copies can be obtained in ERD's Trailer 4302 Library.**

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Appendix B

B-518 Area Vapor Extraction Treatability Test

Appendix B
B-518 Area Vapor Extraction Treatability Test

B-1. Introduction

A vapor extraction treatability test was performed at the B-518 Area to evaluate the applicability and effectiveness of vapor extraction as a remediation technique and to provide preliminary design parameters. The B-518 Area consists of the partially asphalted area within about 100 ft of B-518 (Fig. B-1). B-518 was constructed in 1959 for use as a gas cylinder, solvent, and oil drum storage dock area. Anecdotal information indicates that damaged and/or leaking drums were taken to the edge of the asphalt on the southeast corner of the facility and allowed to drain onto unpaved ground (Thorpe *et al.*, 1990).

The subsurface near B-518 was initially investigated in 1984 with eight boreholes drilled to a depth of about 60 ft (Carpenter, 1984). Subsequently in 1988 and 1989, nine additional boreholes were drilled to the water table (Dresen *et al.*, 1989; Thorpe *et al.*, 1990). The vadose zone at this location is about 110 ft thick, and consists of heterogeneous interfingered silt, clay, and sand with minor amounts of clayey gravel and gravely sand. Soil vapor surveys to depths of 5 to 15 ft were also conducted in 1988 and 1989 (Fig. B-1).

Results of the investigations in 1989 indicate that up to 6,400 ppb total VOCs existed in soil from SIB-518-001 at a depth of about 20 ft; of this total, 6,100 ppb was TCE. Preliminary numerical modeling performed to evaluate VOC migration by gaseous diffusion (Appendix G in Isherwood *et al.*, 1990) indicates that the VOCs in the vadose zone at this location will impact ground water with TCE concentrations above the MCL in the future. Therefore, DOE/LLNL plan to remove VOCs from the vadose zone by vapor extraction.

A vapor extraction treatability test was conducted from June 1 to June 4, 1993. Soil vapor boring SVB-518-201 was completed as a soil-vapor extraction well in March 1993 to conduct this test (Fig. B-2). The test consisted of extracting vapor from SVB-518-201 and monitoring the effects in nearby vadose zone probe SIP-518-101, located about 50 ft east of the extraction well (Figs. B-1 and B-2). SIP-518-101 is screened from 55 to 61 ft in 1 to 2 ft of sandy gravel surrounded by sandy and clayey silt. The extracted vapor was treated by two GAC canisters in series prior to atmospheric discharge (Fig. B-2).

SVB-518-201 was screened from depths of 34 to 50 ft where up to 35 ppb total VOCs in soil were reported in the initial source investigations. The lithology in this interval consists of primarily silty gravel with interfingered clayey silt. The sample containing the 35 ppb total VOCs was held 9 days before analysis. There is some evidence that holding time can greatly affect reported concentrations (Jenkins *et al.,* 1993). Data collected in October 1993 from a probe about 20 ft away indicated that up to 4.3 ppm total VOCs exist near the interval screened in this well.

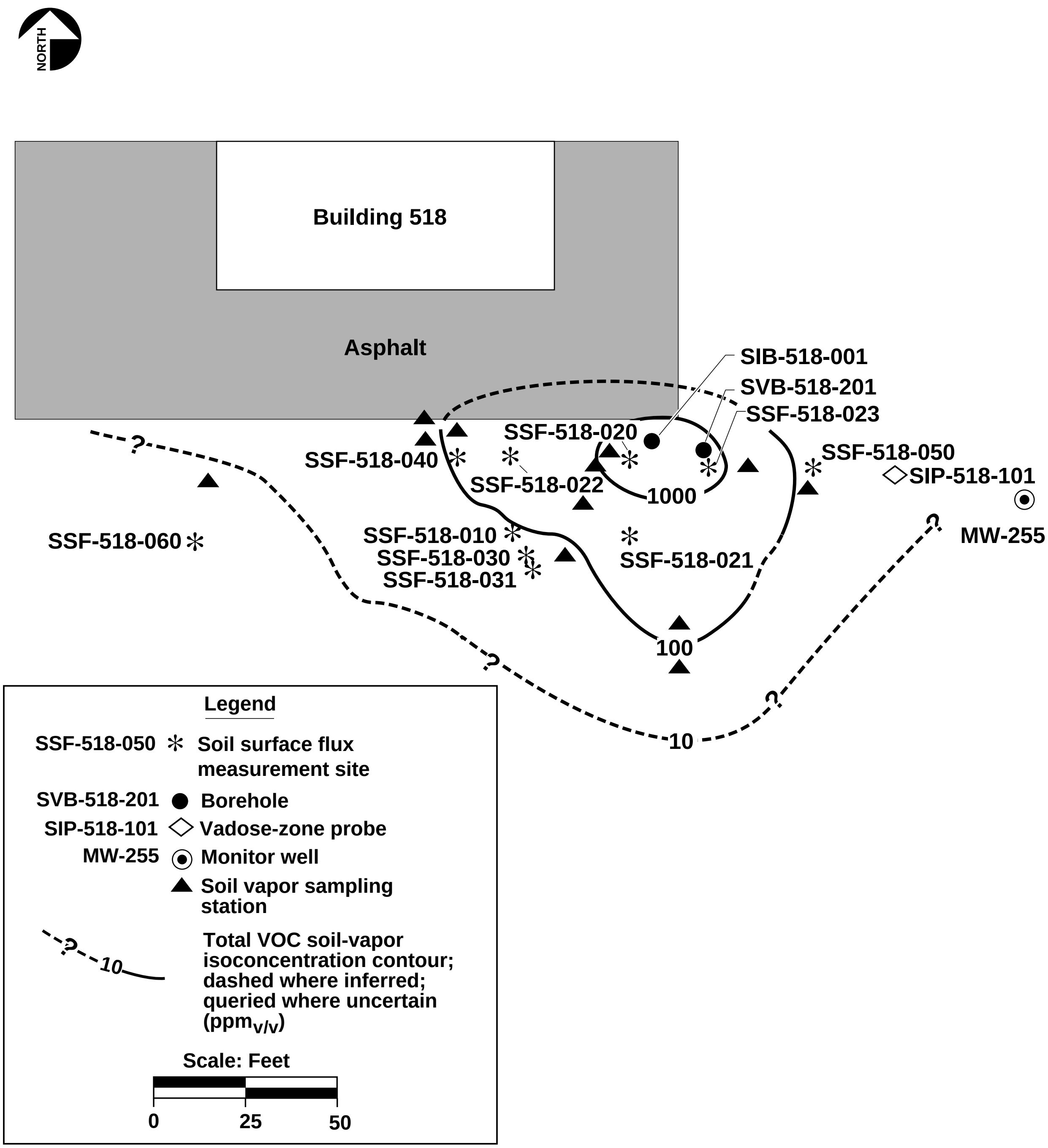

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Figure B-1. Sampling locations and total VOC soil-vapor concentrations at 5-ft depth (modified from Isherwood *et al.*, 1990).

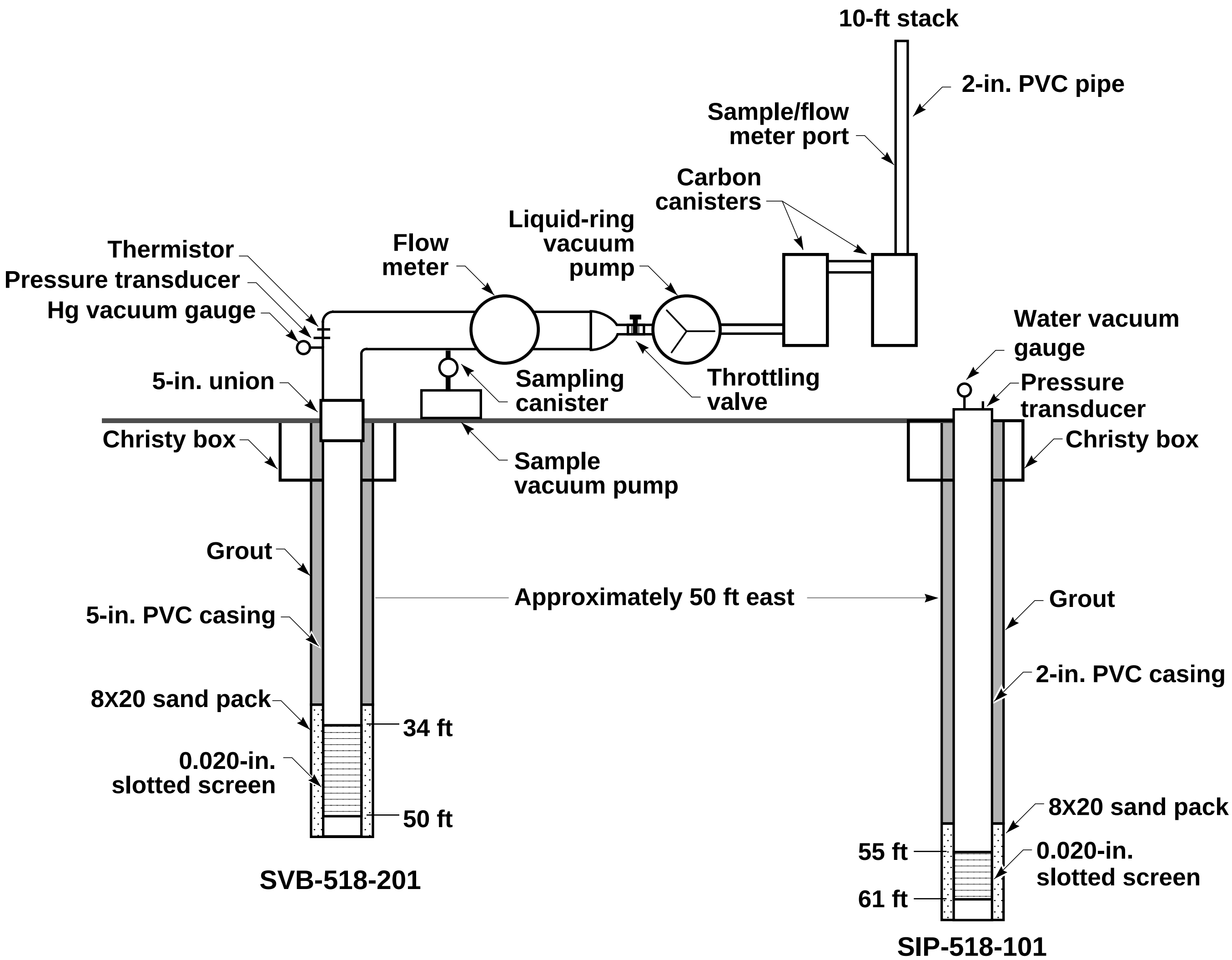

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Figure B-2. B-518 soil-vapor extraction test setup.

B-2. Test Setup

To conduct this test, a liquid-ring vacuum pump was connected to the extraction wellhead via a 5-in. PVC pipe (Fig. B-2). A number of monitoring devices were attached to the PVC pipe throughout the system. Figure B-2 shows the extraction system assembly. A 0- to 30-in. Hg vacuum gauge and a pressure transducer were placed at the wellhead to monitor the vacuum at the well. The Hg vacuum gauge was used to calibrate and verify the pressure transducer measurements at the extraction well. To evaluate whether the daily ambient temperature changes affected the pressure transducer, a thermistor was installed to monitor the air temperature at the wellhead. Data from all the sensors except the Hg vacuum were recorded by a data logger. A sample port and small vacuum pump located about 3 ft from the wellhead were used to collect vapor samples.

A flow meter (Merian gauge), a 0- to 8-in. water differential pressure gauge (Magnahelic), and a pressure transducer were installed upstream of the liquid-ring vacuum pump. The liquid-ring vacuum pump was powered by a three-phase generator. A ball valve located on the pump assembly was used to control the vacuum at the wellhead. Two GAC canisters were attached via a 2-in. PVC pipe downstream of the pump to treat the VOCs (primarily TCE) from the vapor stream. A 10-ft stack was installed for sampling effluent gas and measuring air flow rates.

A pressure transducer and a 0- to 1-in. water vacuum gauge were used to measure the pressure at the vadose zone probe.

The pressure transducers were calibrated *in situ* by linear regression analysis from vacuum gauge readings and temperature sensor responses collected prior to vapor extraction. All the thermistors were factory-calibrated. The flow meter was calibrated to 80 scfm in the laboratory with a flow meter calibration station.

On June 1, prior to starting the soil-vapor extraction system, pressure measurements were continuously recorded at the wellhead and at probe SIP-518-101, and averages were logged by the data logger at 15-minute intervals for 72 h.

B-3. Test Description

Vapor extraction began on June 2, 1993, and continued for approximately 8 h. The vacuum pump was set at a constant vacuum. However, throughout the test, the actual flow rate decreased from an initial flow rate of 130 to a sustained flow rate of about 100 scfm. During the test, the effects of soil-vapor extraction were measured by continuously recording the vacuum in probe SIP-518-101 and periodically measuring water levels in nearby monitor well MW-255 (Fig. B-1), screened from 115 to 124 ft in the first water-bearing zone. Ambient air temperature, wellhead temperature, and pressure drop across the flow meter were also logged throughout the test. During the first testing day, soil surface flux (SSF) measurements were made at SSF-518-020, SSF-518-030, SSF-518-040, SSF-518-050, and SSF-518-060 (Fig. B-1), using a soil surface flux chamber. Each location was measured prior to pumping, at midday during vapor extraction and after pumping stopped to evaluate the effect of vapor extraction on surface VOC emissions.

During the first day of pumping, we determined that the 0- to 1-in. water vacuum gauge at the probe was undersized, so it was replaced with a 0- to 5-in. unit. In addition, the vapor flow rate could not be measured during the first day due to a malfunction in the flow meter. A Kurzt hot wire anemometer was installed in the exhaust stack for manual vapor flow readings the following day. An approximate vapor flow rate for the first day was calculated using a correlation between vacuum and flow data obtained during the second day of testing.

After the wellhead vacuum had stabilized, we collected five vapor samples using evacuated stainless steel spheres, following the procedures specified in Method 18 in 40 CFR, part 60.

On June 3, 1993, additional testing was performed to correlate applied vacuum to vapor flow. The vacuum at the wellhead was incrementally increased from 0.36 to 11.55 in. of Hg. The flow rate was determined using the Kurzt hot wire anemometer installed in the exhaust stack. After the pressure and flow rate stabilized at each step, vapor samples were collected using evacuated stainless steel spheres.

Surface flux measurements were made on the second day of testing at location SSF-518-020 (Fig. B-1) before pumping was started, at midday and after pumping stopped.

B-4. Results

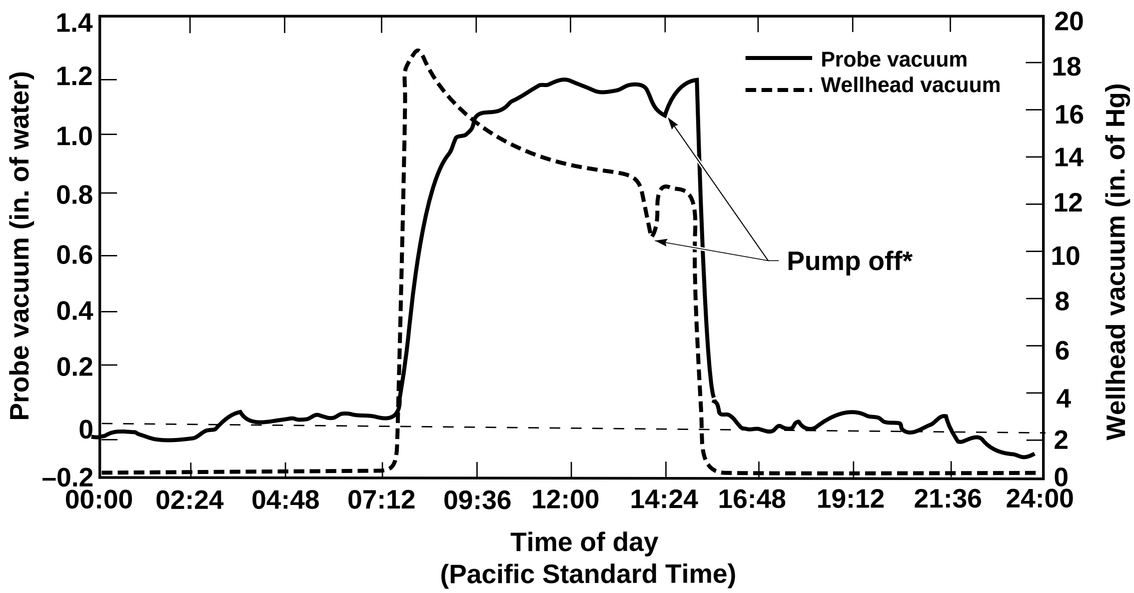
Table B-1 summarizes the pressures at the extraction wellhead and observation probe SIP-518-101, TCE concentrations in the vapor, and estimated flow rates at specific times for the first day of testing. SIP-518-101 showed significant response to vapor extraction from SVB-518-201 (Fig. B-3). Over the course of the test, the vacuum in the probe increased while the vacuum at the wellhead decreased. The increase in pressure at the probe over time may indicate a gradual propagation of a vacuum front through the relatively low-permeability materials between the extraction well and the probe.

Table B-1. Selected vapor extraction test data using relatively constant vacuum, June 2, 1993.

Time (minutes)	Wellhead vacuum (inches of Hg)	Probe vacuum (inches of water)	TCE concentration ($ppm_{v/v}$)	Flow rate (scfm)[a]
7.5	18.0	0.25	50	130
15.0	18.8	0.63	340	140
75.0	15.9	1.01	448	120
210.0	14.2	1.19	390	110
443.0	12.7	1.21	296	100

Note: time-weighted average extracted vapor concentrations are presented in Table 1 in Section 2.3.

[a]Flow meter failed, therefore, flow rate was estimated from wellhead vacuum to flow rate relationship.



*** Vacuum extraction system turned off to check the flow meter**

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Figure B-3. Probe and wellhead vacuum over time (June 2, 1993).

TCE concentrations appeared to slightly decrease by the end of the first day of extraction (Fig. B-4). The measured TCE concentrations were adjusted using the Ideal Gas Law to compensate for the vacuum in the sample spheres. As discussed above and shown in Figure B-3, the vacuum in SVB-518-201 also decreased throughout the test.

As shown in Figure B-5, TCE surface flux concentrations measured at location SSF-518-020 generally decreased, similar to the wellhead vacuum curve in Figure B-4. Although each SSF location was somewhat affected by the vapor extraction process, SSF-518-020 was the only location to show a measurable effect. The results for the variable vacuum test over time are presented in Table B-2.

Table B-2. Selected vapor extraction test data using variable vacuum, June 3, 1993.

Time (minutes)	Wellhead vacuum (inches of Hg)	Probe vacuum (inches of water)	TCE concentration ($ppm_{v/v}$)	Flow rate (scfm)
57	0.36	0.00	456	1.9
90	0.69	0.00	525	3.5
119	1.10	0.00	546	7.6
173	1.47	0.00	555	9.9
200	3.13	0.20	525	22.9
241	5.80	0.40	498	41.5
323	11.55	1.10	496	86.2

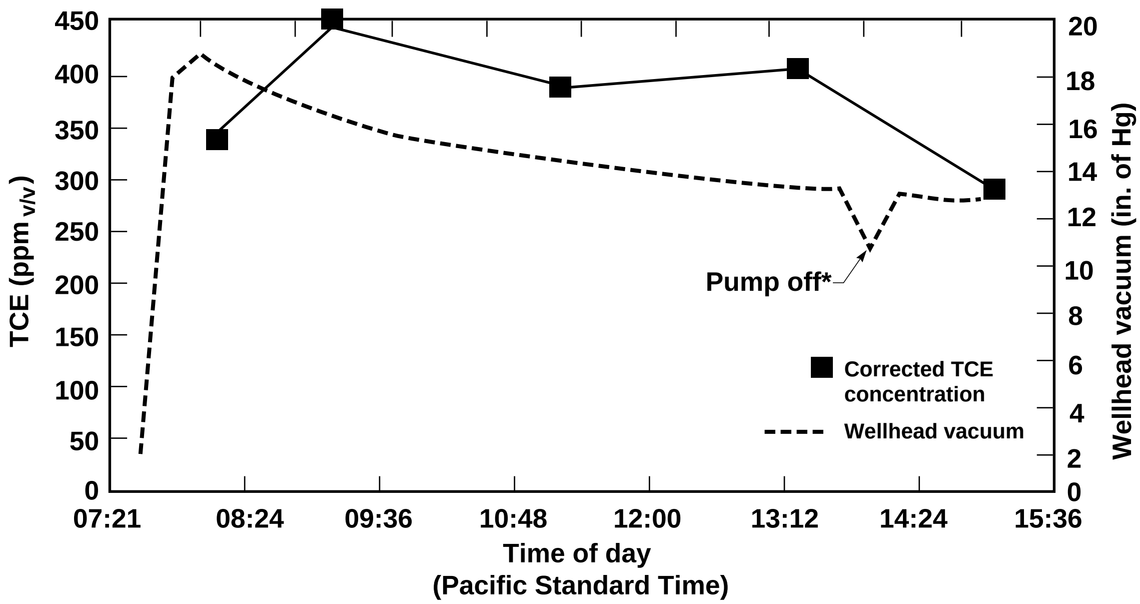
Note: time-weighted average extracted vapor concentrations are presented in Table 1 in Section 2.3.

The probe vacuum response to the variations of applied vacuum at the extraction well is presented in Figure B-6. Although the magnitude of the vacuums differ, the response pattern measured at the probe closely followed the pattern measured at the extraction wellhead. The relation between the vapor extraction rate and wellhead vacuum is shown in Figure B-7. These data indicate response in the probe to changing vacuum in the extraction well at a horizontal distance of about 50 ft.

The temperature measurements from the thermistor indicate that temperature did not seem to have a significant effect on the output of the pressure transducer. The water level in MW-255 did not appear to be affected by the vapor extraction.

B-5. Conclusions

The results of this soil-vapor extraction treatability test indicate that vapor extraction is an applicable and effective technique for removing VOCs from the vadose zone beneath the B-518 Area. Vapor extraction well SVB-518-201 yielded about 40 $\pm$ 10 scfm under an applied vacuum of 6 in. Hg. Two to four vapor extraction wells completed in similar sediments should achieve 80 to 160 scfm total extraction flow under an applied vacuum of about 6 in. Hg. Soil vapor extraction at 100 scfm significantly influenced a vadose zone probe 50 ft away, and GAC effectively treated the extracted VOC vapor.



*** Vacuum extraction system turned off to check the flow meter**

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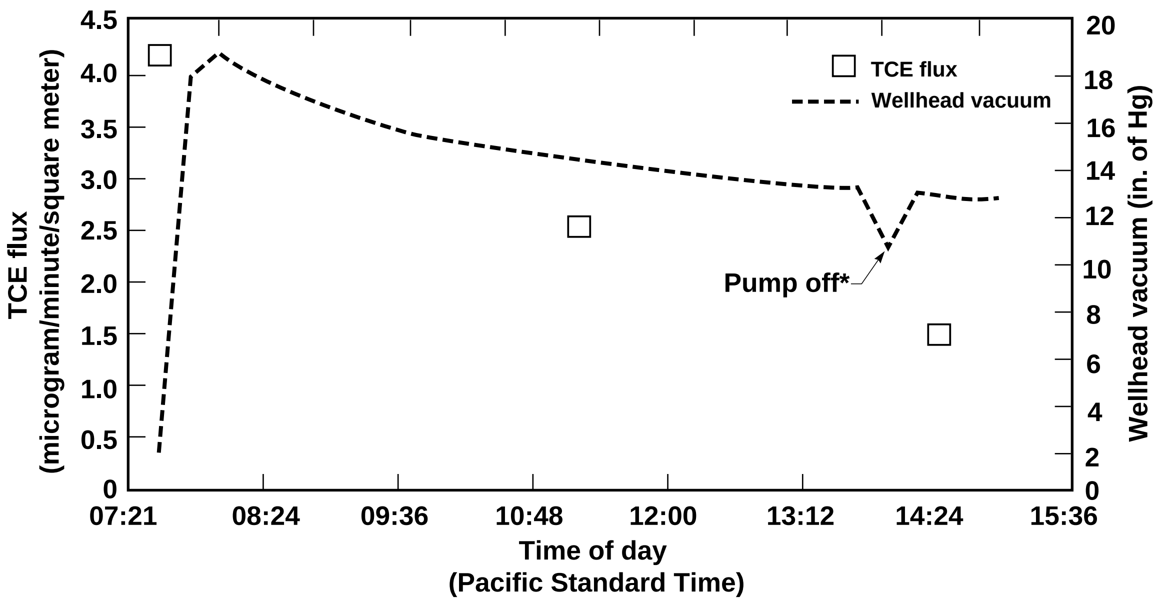
Figure B-4. Wellhead vacuum and TCE concentration over time (June 2, 1993).



* Vacuum extraction system turned off to check the flow meter

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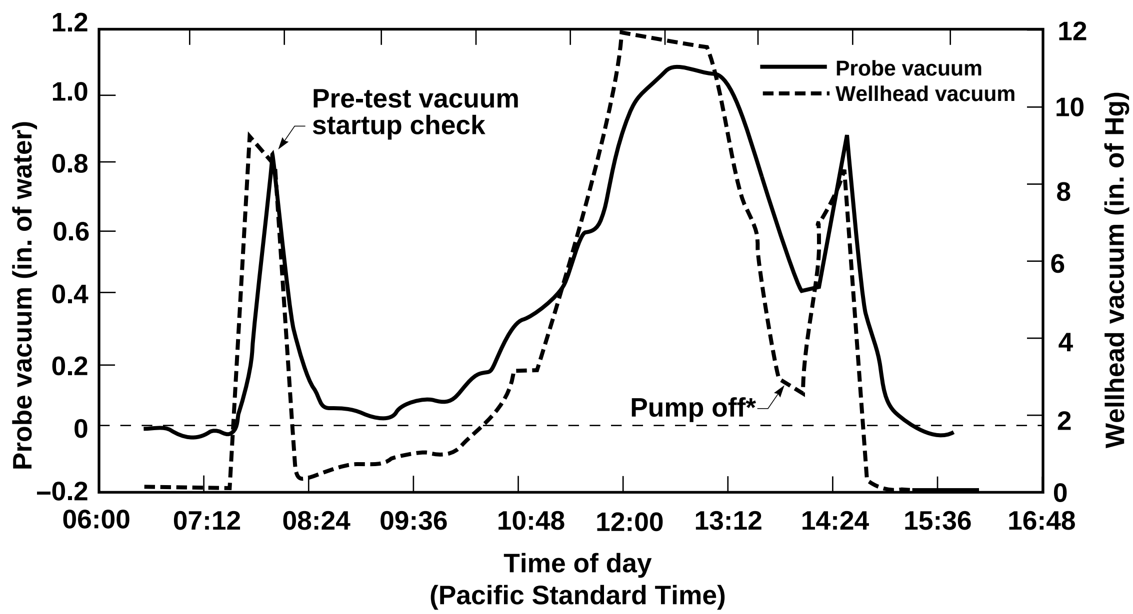
Figure B-5. Wellhead vacuum and TCE flux over time at SSF-518-020 (June 2, 1993).



* Vacuum extraction system turned off to check the flow meter

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Figure B-6. Wellhead and probe vacuum over time (June 3, 1993).

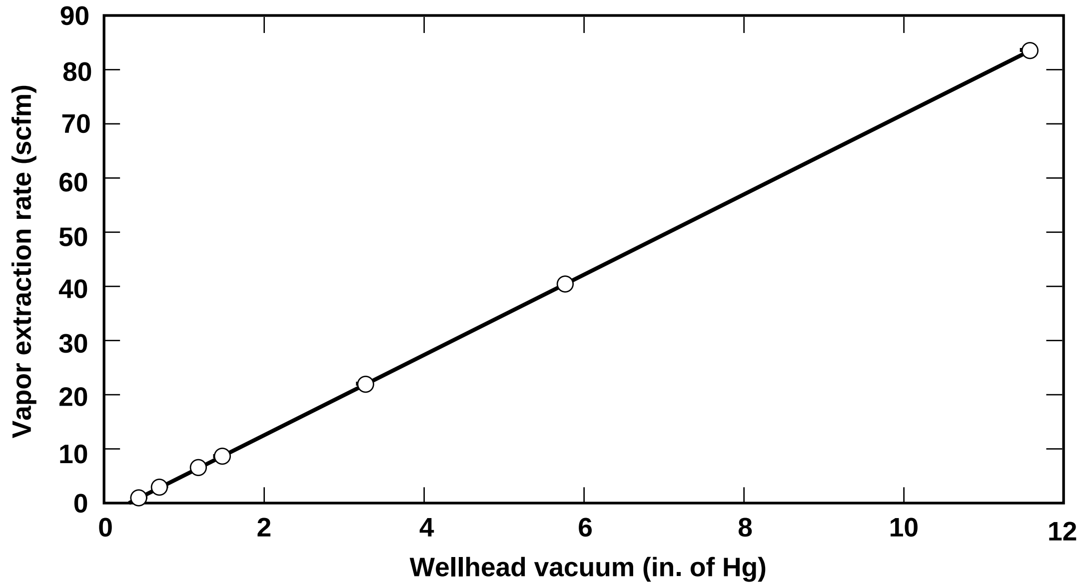

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Figure B-7. Vapor flow rate versus extraction wellhead vacuum for test on June 3, 1993.

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Appendix C

Example TCE Mass Removal Calculation for the B-518 Vapor Treatability Test (June 4, 1993 Data)

Appendix C

Example TCE Mass Removal Calculation for the B-518 Vapor Treatability Test (June 4, 1993 Data)

TCE mass calculations for the B-518 vapor treatability test were made by using the Ideal Gas Law:

$$PV = \frac{mRT}{MW}$$

where:

$$P = \text{Pressure} = 1 \text{ Standard Atmosphere (ATM)}$$

$$T = \text{Temperature} = 273 \text{Kelvin (K), Standard Temperature}$$

$$MW = \text{TCE molecular weight} = 131.4 \text{ kg/kg mole}$$

$$R = \text{Universal gas constant} = 0.082 \frac{(m^3 \text{ ATM})}{(\text{kg mole K})}$$

$$V = \text{TCE vapor volume } (m^3)$$

$$m = \text{TCE mass (kg)}$$

$$\text{TCE volume} = V = (410 \text{ppm}_{v/v}) \times \left(\frac{1}{10^6}\right) \times (900 \text{ m}^3) = 0.37 \text{ m}^3 .$$

Solving for m gives:

$$m = \frac{PV\ MW}{RT} .$$

Thus, the mass of TCE extracted on June 4, 1993, when 900 m^3 of vapor was extracted at a time-averaged concentration of 400 $\text{ppm}_{v/v}$ TCE, is:

$$m = \frac{(1 \text{ATM}) \times (0.37 \text{ m}^3) \times (131.4 \text{ kg/kg mole})}{\left(\frac{0.082 \text{ m}^3 \text{ ATM}}{\text{kg mole K}}\right) \times 298\text{K}} = 2.0 \text{ kg TCE} .$$

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Appendix D

Vadose Zone Flow and Transport Modeling for the B-518 Area

Appendix D
Vadose Zone Flow and Transport Modeling for the B-518 Area

The NUFT flow and transport code was used to evaluate the effectiveness of vapor extraction at B-518 to reduce the migration of vadose zone TCE to the underlying ground water. The B-518 vadose zone modeling was also used to help understand vadose zone TCE transport in the B-518 Area and to evaluate wellfield design. As discussed in RD2 (Berg *et al.*, 1993), ground water in the B-518 Area contains VOCs above MCLs, and will be treated at TFF.

Two conceptual models were simulated. The first assumed homogeneous sediment properties, and the second incorporated site-specific heterogeneous sediment properties. Homogeneous conceptual models are commonly used initially because they are easily applied and provide reasonable estimates for some of the issues addressed in the early stages of planning a remediation project (e.g., evaluating general feasibility, first-order evaluations of wellfield design, etc.). In later stages, determinations of (1) the most cost effective remediation, (2) the well and screen placements, (3) potential impacts on the ground water from remaining vadose zone contaminants, (4) cleanup time estimates, and (5) closure criteria are likely to depend on the heterogeneous properties of the subsurface under the stress of SVE. For this remedial design, we used both the homogeneous and heterogeneous conceptual models to examine some of the most important basic assumptions that will affect remediation cost and reliability.

We assumed for the B-518 simulations that the ground water beneath the unsaturated zone contained no VOCs, and the simulations did not account for the TCE which already exists in ground water. Therefore, these simulations predict the "incremental" impact of TCE on ground water resulting from transport of TCE from the unsaturated zone to the saturated zone. Analytical data suggest that some of the TCE already in ground water beneath the B-518 Area probably originated from upgradient sources located north of the B-518 Area (Thorpe *et al.*, 1990).

The conceptual models for these simulations (Fig. D-1) incorporated no preferred recharge pathways, no spatial or temporal variations in precipitation, and no ponded water or streams to enhance the downward migration of contaminants through the unsaturated zone. These mechanisms probably operate at the Livermore Site, and may be included in future simulations when additional data are available. The boundary conditions used for the B-518 simulations are presented in Figure D-2.

Both the homogeneous and heterogeneous simulations estimated changes in vadose zone TCE concentrations resulting from SVE at extraction well SVB-518-201. Three-dimensional modeling of vadose zone VOC migration, including the effects of paving and structures on vapor phase transport and surface water infiltration in the B-518 Area, will be applied as needed to evaluate performance and compliance monitoring data.

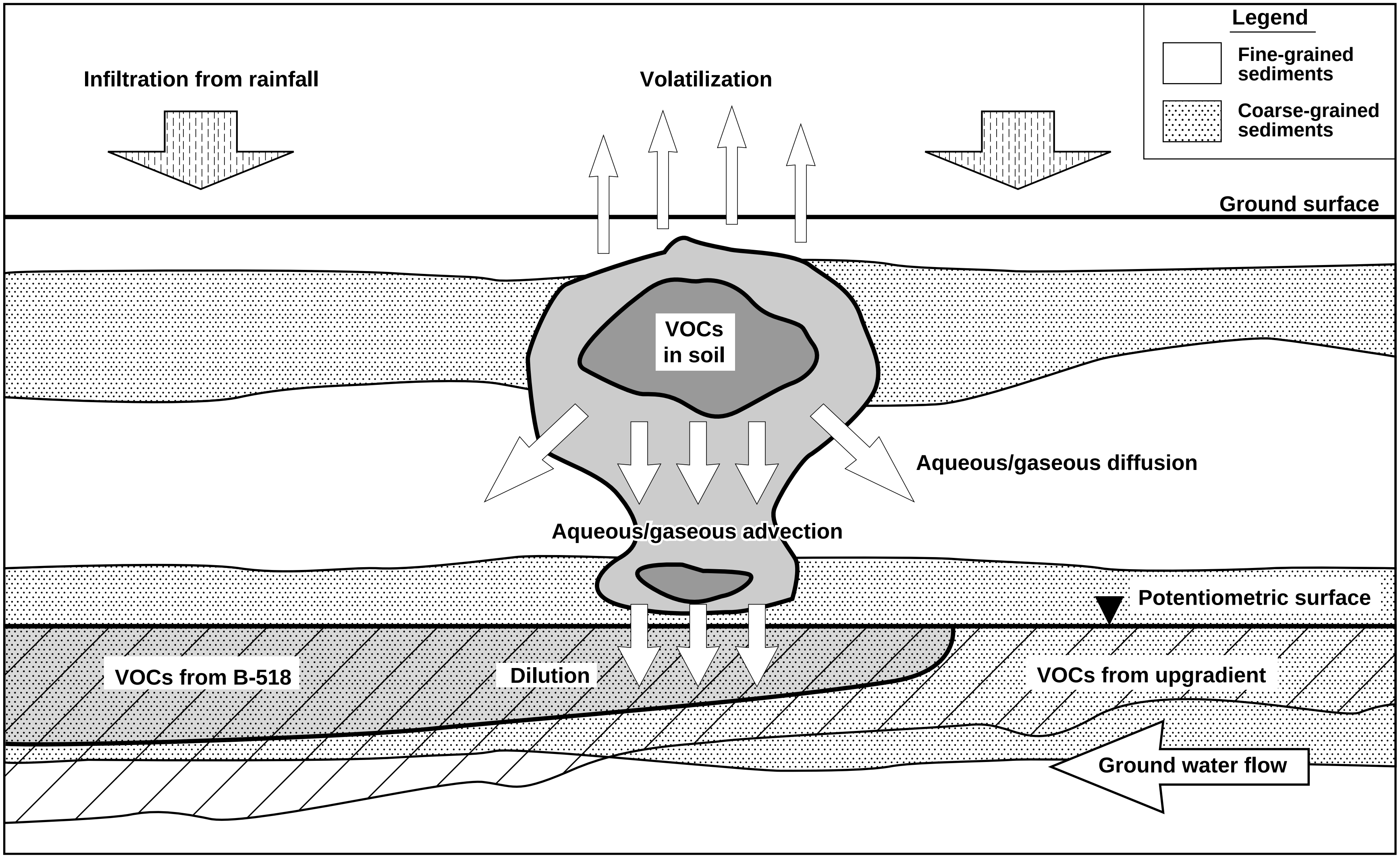

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Figure D-1. Conceptual model used for the B-518 Area vadose zone modeling.

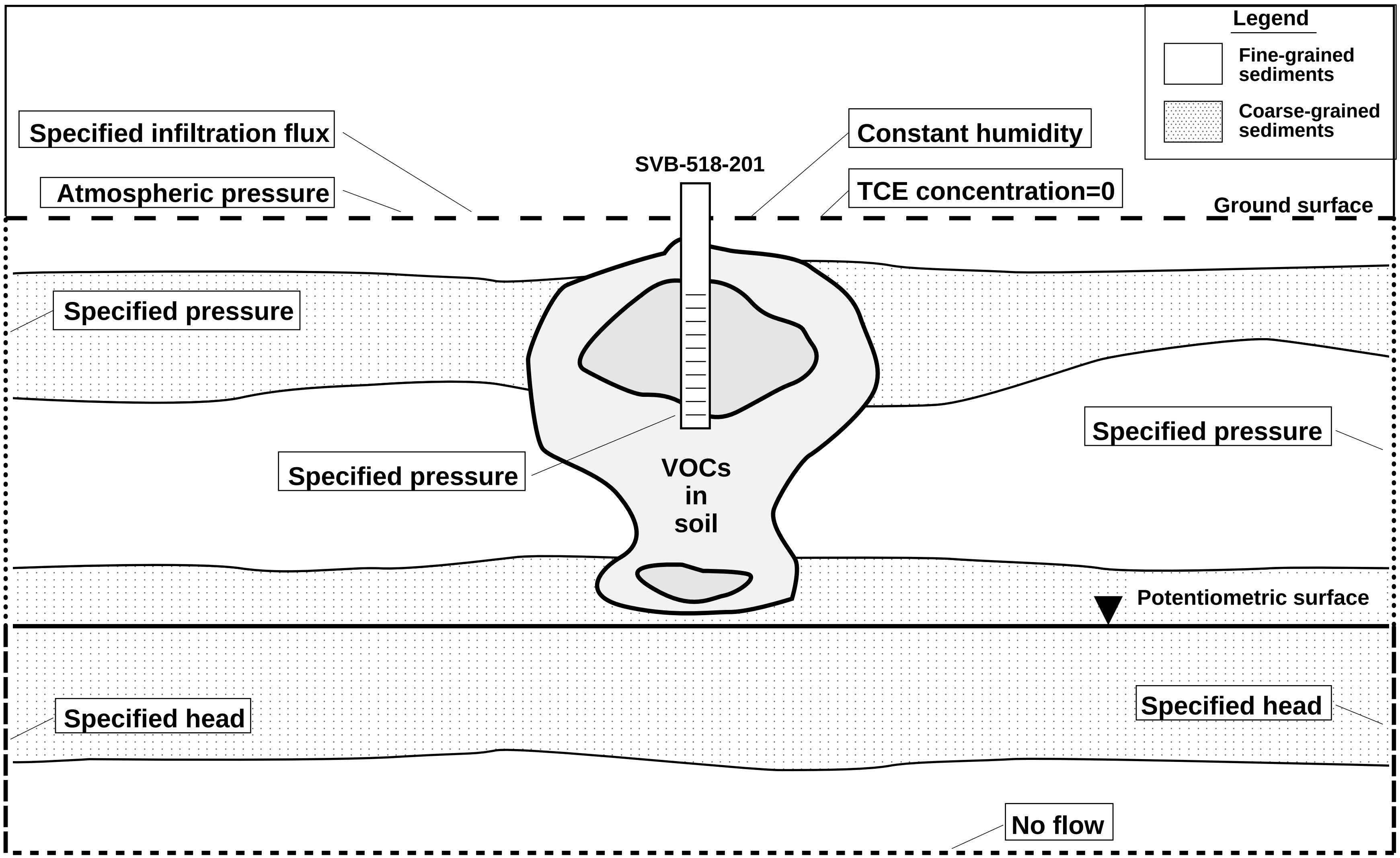

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Figure D-2. Boundary conditions used for the B-518 vadose zone modeling.

D-1. TCE in Sediment

In the subsurface, TCE partitions into the vapor phase by volatilization, the aqueous phase by dissolution, and the solid phase by sorption. The distribution of TCE in sediment was estimated initially from chemical analyses of soil cores. TCE distribution into the vapor, aqueous, and solid phases is dependent on the partition coefficients, porosity, bulk density, and water saturation. These parameters were estimated from laboratory measurements on sediment core samples.

Sediment samples were collected from 18 wells and borings in the B-518 Area. However, only some of the analyses were considered to be suitable for model input because of variations in sample holding times, which may have affected the reported concentrations. Acceptable TCE sediment concentrations were restricted to samples that were analyzed within 3 days of collection because holding time apparently can greatly affect reported concentrations (Jenkins *et al.*, 1993). Accordingly, data from 112 samples collected from 11 borings were input into the model. The input sediment VOC data were then interpolated using a three-dimensional interpolation program (DGI Earth-Vision) that assigned sediment TCE concentrations to specified element locations in a form usable by the NUFT code. Figure 6 in Section 2.4 is an east-west cross section of the interpolated TCE concentrations in the B-518 vadose zone. Based on sediment data collected prior to the treatability test, the interpolation program estimated that 22 kg of TCE currently remains in the vadose zone.

The complexity of the conceptual model was increased in steps from very simple to more complex, i.e., from a homogeneous sediment model to a heterogeneous sediment model. The modeling steps and information obtained from each step are summarized below.

D-2. Case 1: Two Dimensional Homogeneous Sediment Properties

The B-518 Area vadose zone was simulated as an area with a radius of 262 ft, which extends beyond the estimated area affected by vapor extraction. An applied wellhead vacuum input parameter of 14 in. Hg resulted in a simulated flow rate of 100 to 140 scfm based on calibration to the treatability test. The unsaturated zone and saturated zone were assumed to be about 35 m (115 ft) and 10 m (33 ft), respectively. For Case 1, the sediment type was assumed to be a homogeneous silty sand, which is the predominant sediment in the B-518 Area subsurface. The SVE well, SVB-518-201, was located along the central axis of the model domain. In the model, the sediment was assumed to be saturated with water below the 115-ft depth. The horizontal ground water velocity was specified at 1 m/y (Appendix G in Isherwood *et al.*, 1990). Diffusive exchange of TCE with the atmosphere was simulated. Ten percent of the annual average precipitation of 11 in./y, or 1.1 in./y, was assumed to infiltrate into the vadose zone.

D-2.1. Calibration

Prior to the vadose zone cleanup simulations, the model was calibrated to measurements made during the treatability test (Section 2.3) to better approximate field conditions. The objective was to find those values of the more uncertain physical input parameters that would match simulation results to (1) the measured vapor flow rate in scfm, (2) the TCE concentrations in the effluent air stream (in $ppm_{v/v}$), and (3) the total TCE mass removed (in kg) during the 8-h test. The calibrated model indicated that the total mass of TCE in the vadose zone may be up to five times greater (110 kg) than the 22 kg indicated by the TCE soil analytical data (Section D-1). Accordingly, the total TCE mass in the subsurface was conservatively increased by a factor of five for further numerical simulations using the homogeneous model.

D-2.2. No-Action Simulation

A no-action simulation was conducted to estimate what effect TCE concentrations in the vadose zone would have on the underlying ground water if no remedial action was implemented. The no-action simulation estimated a maximum ground water TCE concentration of 281 ppb after 218 y. Modeling results in Appendix G of the FS (Isherwood *et al.*, 1990) predicted a peak concentration of 17 ppb at 55 y. The results of the simulation in this RD report are higher because the initial mass estimate is significantly higher (by a factor of five), and this simulation included the effects of rainfall, infiltration, and aqueous advection, as well as gaseous advection. In addition, the model presented in Appendix G of the FS assumed a TCE degradation half-life of 50 y, whereas the simulation described in this report conservatively assumed no TCE degradation.

D-2.3. Vadose Zone Cleanup Simulation

Case 1 simulations were conducted using multiple runs in pairs. The first part of the paired run simulated SVE over a finite duration; the second part evaluated TCE migration to ground water after SVE ceases. SVE duration was extended by one year for successive simulation pairs. Table D-1 presents estimated TCE concentrations in ground water after 1, 3, and 4 y of continuous SVE. Model results indicate that the TCE concentrations in ground water fall below the 5 ppb MCL after 3 to 4 y of continuous SVE, and that SVE at SVB-518-201 reduces TCE concentrations in soil within 50 m (160 ft) of this well. As expected, the model also suggests that ground water movement in the saturated zone plays a significant role in attenuating TCE concentrations in ground water.

Table D-1. Estimated TCE concentrations in ground water for the homogeneous case after various years of SVE.

End of Year	TCE concentration (ppb)
1	17.7
3	8.6
4	4.3

D-3. Case 2: Two Dimensional Heterogeneous Sediment Properties

Case 2 differs from Case 1 only in that it includes heterogeneity in sediment properties. The objective of the Case 2 simulation was to assess the potential effects of variable sediment properties on the effectiveness of SVE, and on TCE ground water concentrations.

Based on sediment data from B-518 and throughout LLNL, 11 representative material types, ranging from coarse gravelly sand to fine clayey silt, were defined for Case 2. The three-dimensional spatial distribution of the material types at B-518 was estimated using site-specific borehole data and a geostatisitical interpolation algorithm. A similar algorithm was used to project the three-dimensional data onto a two-dimensional computational grid. Initial saturated hydraulic conductivities were modified during model calibration, while their relative spatial distribution was held constant.

The model was calibrated to the results of the treatability test discussed in Section 2.3. A fixed wellhead vacuum of 14 in. Hg was applied to the model. Saturated hydraulic conductivities and initial sediment TCE concentrations were modified during the calibration process until measured air flow and TCE removal rates were matched. Calibrated soil hydraulic conductivities and other parameters are presented in Table D-2.

Table D-2. B-518 calibrated material properties.

Soil number/type	Saturated hydraulic conductivity (m/sec)	Porosity	TCE K_d
1 (clayey silt)	6.8E-07	0.4	2
2	1.4E-06	0.4	2
3	2.7E-06	0.4	1
4	5.4E-06	0.4	1
5	2.2E-05	0.3	0.5
6	2.2E-05	0.3	0.5
7	4.3E-05	0.3	0.5
8	8.7E-05	0.3	0.5
9	1.7E-04	0.3	0.5
10	3.5E-04	0.3	0.5
11 (gravelly sand)	6.9E-04	0.3	0.5

D-3.1. Calibration

The results of calibrating Case 2 to the treatability test suggest that up to 44 kg of TCE may exist in the B-518 Area subsurface, twice the original estimate of 22 kg from interpolated soil TCE concentrations (Section D-1), and two and one-half times less than that estimated by the homogeneous case (Section D-2.1). Accordingly, the total TCE mass in the subsurface was conservatively increased by a factor of two for further numerical simulations using the heterogeneous model.

D-3.2. No-Action Simulation

A no-action simulation was conducted to estimate TCE concentrations in ground water if no remedial action was taken. The no-action simulation estimated a maximum ground water TCE concentration of 280 ppb after 225 y.

D-3.3. Vadose Zone Cleanup Simulations

Case 2 SVE simulations were also conducted using multiple runs in pairs. The first part of the paired run simulated SVE over a finite duration; the second part evaluated TCE migration to ground water after SVE ceases. SVE duration was increased by one year for each successive simulation pair. Table D-3 presents estimated TCE concentrations in ground water after 1, 5, and 6 y of continuous SVE. Case 2 results suggest that TCE concentrations are below the 5 ppb MCL after 5 to 6 y of continuous SVE, and that SVE at SVB-518-201 reduced TCE concentrations in soil to maximum concentrations of 20 to 30 ppb within 50 m (160 ft) of the well (Fig. D-3).

Table D-3. Estimated TCE concentrations in ground water for the heterogeneous case after various years of SVE.

End of year	TCE concentration (ppb)
1	17.1
5	5.9
6	4.9

D-4. Discussion of Model Results

Both the homogeneous and the heterogeneous models estimate a similar TCE impact on ground water. However, the homogeneous model estimates a shorter cleanup time (3 to 4 y versus 5 to 6 y). This can be attributed to the lower permeability layers that limit vertical vapor flow in the heterogeneous case.

Figure 7 in Section 2.4 presents the estimated rate of TCE removal by SVE for both models. Both models estimate that most of the TCE mass is removed in the first few years. The homogeneous and the heterogeneous models estimate 77% and 79%, respectively, of the total initial TCE mass is removed within the first two years of continuous extraction. Mass removal drops off rapidly thereafter. The estimated cumulative volume of TCE removed approaches asymptotic levels of 17.5 gal (96.5 kg) for the homogeneous case, and 6.7 gal (36.8 kg) for the heterogeneous case.

D-5. Conclusions and Plans for Future Work

Based on the more conservative simulations of the heterogeneous case, and recognizing the approximate nature of model predictions, the GAC in the B-518 Vapor Treatment Facility system will be designed for a TCE mass loading of 200 kg, approximately twice the calibrated mass estimate from the homogeneous case. This system will also be designed to operate for at least 5 to 6 y. The higher design load will also assure treatment of the other VOCs (PCE, 1,1-DCE) in the extracted vapor. The simulations were run assuming SVE at well SVB-518-201 only. However, the addition of another SVE well, SVB-518-204, and air-inlet well, SVB-518-202, should expedite cleanup. These design contingencies and the additional system capacity should compensate for the uncertainty inherent in this, or any other unsaturated zone flow and transport model. In any event, the SVE system is expected to operate over a much shorter time scale (3 to 6 y) than the ground water cleanup for this area, which may take several decades (Berg *et al*., 1993).

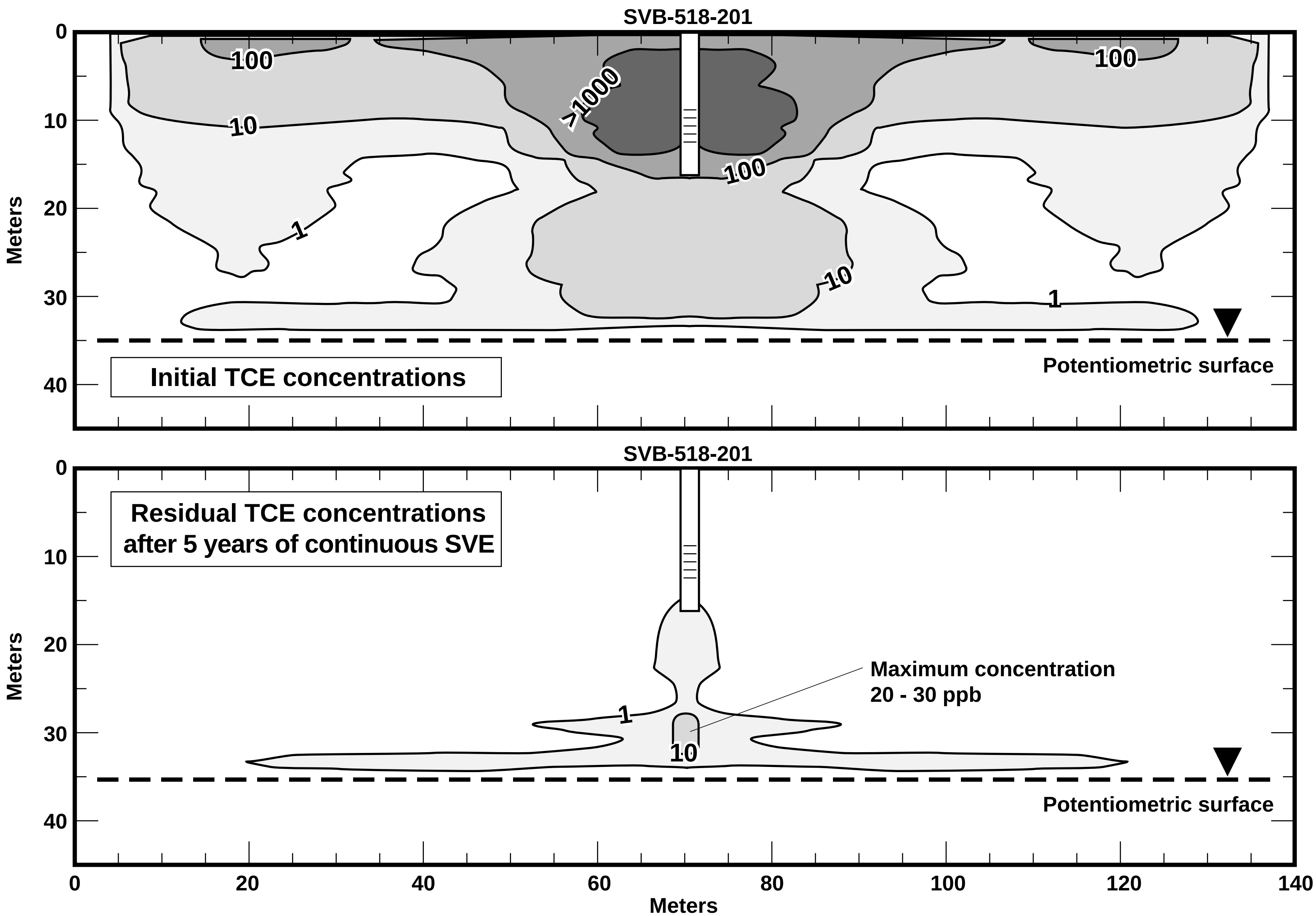

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Figure D-3. Initial and residual TCE concentrations (ppb) in soil in the B-518 Area.

A heterogeneous, three-dimensional simulation with SVE at SVB-518-201 and SVB-518-204, and air-intake at SVB-518-202 is planned for the future. We plan to present the results of this simulation, as well as details of the modeling described in this report, in a separate technical report.

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Appendix E*

BAAQMD Authority to Construct Air Discharge Conditions

***NOTICE: Appendix E exists only in hard copy. Hard copies can be obtained in ERD's Trailer 4302 Library.**

Bay Area Air Quality Management District Authority to Construct Air Discharge Conditions will be included in the final documents

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Appendix F

Operations and Maintenance Quality Assurance/ Quality Control Plan

Appendix F
Operations and Maintenance Quality Assurance/Quality Control Plan

F-1. Introduction

This QA/QC plan has been developed in support of the O&M of the B-518 Vapor Treatment Facility for the vapor extraction system located southeast of B-518. This plan was prepared to meet the O&M requirements of the B-518 Vapor Treatment Facility using the American Society of Mechanical Engineers (ASME) NQA-1-1989 Edition as a guideline.

The purpose of this plan is to define the quality objectives and areas of responsibility in accordance with the requirements of the O&M of the B-518 Vapor Treatment Facility.

F-2. Organization

This section documents the organizational structure, functional responsibilities, levels of authority, and lines of communications for those aspects of the O&M of the B-518 Vapor Treatment Facility that affect quality.

Figure F-1 shows the organizational structure for QA activities. The descriptions below generally describe the QA responsibilities of those mainly involved in carrying out the QA program for the O&M of the B-518 Vapor Treatment Facility. The LLNL ERD Livermore Site Restoration Section Leader, the Quality Assurance Manager, the Remediation Engineer, and the other individuals shown in Figure F-1 have the following responsibilities:

- The Livermore Site Restoration Section Leader (LSRSL) issues this QA plan and periodically reviews its implementation. The LSRSL may request an independent review or formal audit of the QA program.

- The Quality Assurance Manager (QAM) is responsible for the development and implementation of the QA plan, establishment and control of the QA document files, coordination with appropriate project personnel to assure compliance within groups over which the quality organization has no administrative control, and development of tracking and reporting systems to provide management visibility of implementation activities and results.

- The Remediation Engineer (RE) is responsible for overseeing facility startup and monitoring its performance and operations.

- The LLNL Plant Engineering Project Manager (PEPM) reports to the ERD LSRSL and RE. The PEPM is Plant Engineering's primary contact with ERD for each assigned project. Working as the project team leader, the PEPM is responsible for achieving the objectives of each specific project within the allocated budget and schedule while meeting the established performance criteria, as well as DOE, LLNL, and regulatory standards.

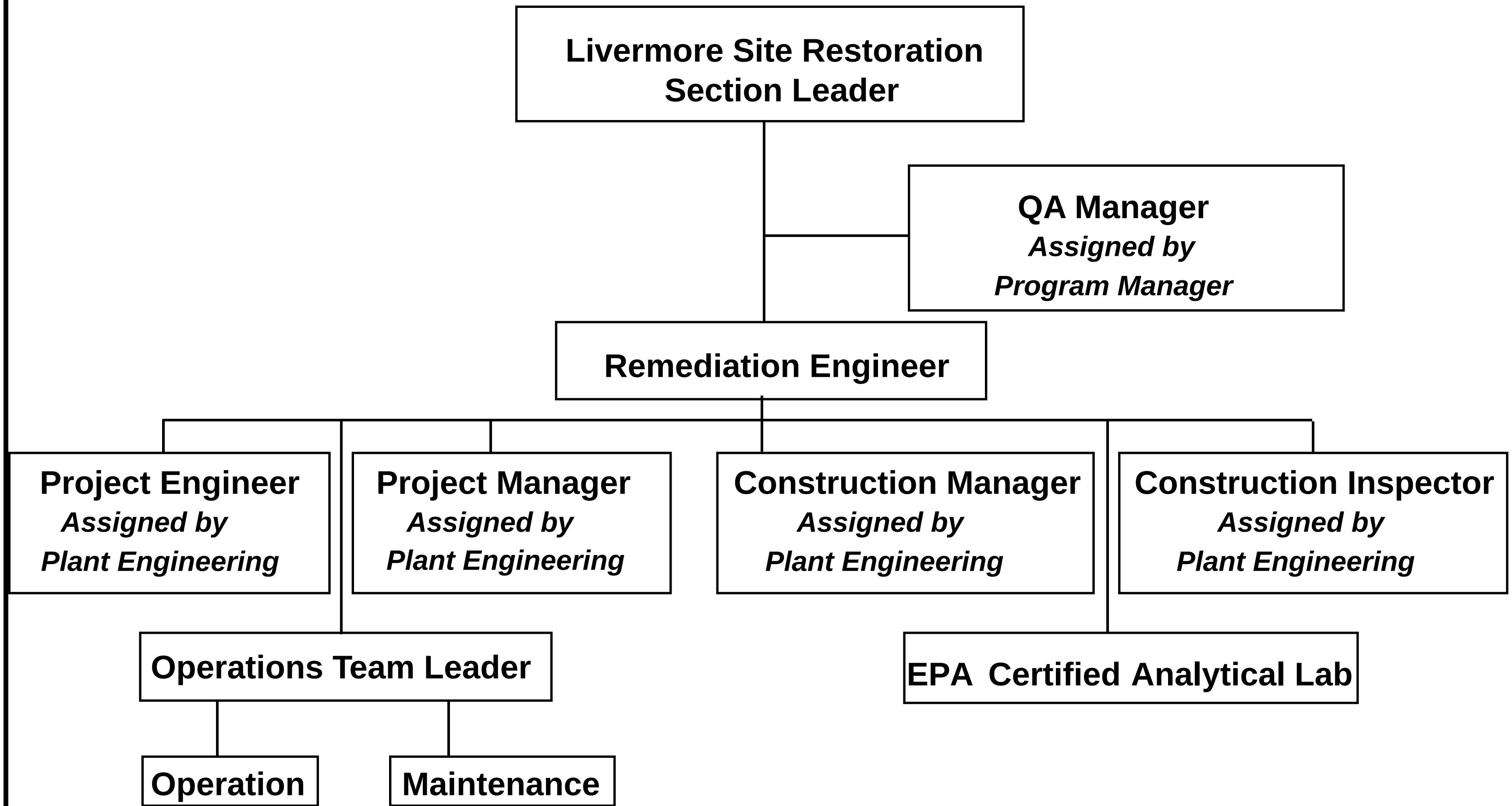

Figure F-1. Organization chart for operation and maintenance quality assurance/quality control for the B-518 Vapor Treatment Facility.

- The LLNL Plant Engineering Project Engineer (PEPE) performs the design or monitors and provides direction to engineers/architects with regard to design concepts, schedule, and budget. The PEPE reports operationally to the PEPM.

- The Construction Manager (CM) acts as the single point contact with construction subcontractors, and reports and advises on status, projected cost, and time of completion. Working in conjunction with the Construction Inspector, the CM protects LLNL's interest by assuring that all work is accomplished safely and in conformance with the contract documents. The CM reports operationally to the PEPM.

- The Construction Inspector (CI) will perform all inspector's duties as specified in the "Construction Inspector's Policy and Procedures Manual," the "Construction Manager Manual," and this QA plan. The CI is assigned to specific projects as the LLNL field representative, and provides quality control and status of all construction activities. The CI reports operationally to the CM.

- The Operations Team Leader (OTL) is responsible for the day-to-day maintenance and operation of the treatment facility. This includes scheduling required maintenance and ensuring that the maintenance requested is completed in a timely fashion.

- State Certified Analytical Laboratories using EPA methods are responsible for providing independent chemical analytical results on soil and vapor samples. For the B-518 Vapor Treatment Facility, these samples are submitted as part of the self-monitoring program required by LLNL's discharge permit, in addition to operational testing samples collected prior to the official operation of a facility and routine samples taken to evaluate facility performance.

F-3. Quality Assurance Program

This section covers objectives, quality goals, and QA levels. The procedures for implementation of QA are included in the plan or cited in the list of codes, standards, and specifications (Table F-1).

The objectives of the project supported by this QA plan are to:

- Assure excellence in maintenance services and operations to achieve quality.

- Provide the QA requirements to meet all programmatic and institutional needs.

This QA plan defines the process for providing confidence that these QA objectives will be achieved and that achievement will include due consideration for health, safety, property, and the environment. Table F-2 shows a list of auditable records (including responsible personnel) that are required to document compliance with the requirements of this plan. Table F-3 shows the 18 elements of NQA-1 and their applicability to the Livermore Site Restoration Section activities.

Table F-1. Applicable Codes, Specifications, and Standards for Operation and Maintenance QA for the B-518 Vapor Treatment Facility.

"LLNL Procurement Manual," Vol II, Books 1, 2, and Book 4 (Construction Subcontract Manual)
"LLNL Plant Engineering Manual," Volumes 1-5, latest revision
"LLNL Plant Engineering Drafting Manual," PEL-P-02065
"Guidelines For In-House Design Reviews and Project Presentations," Frank Tokarz/ Roger Lake, Plant Engineering Department, Engineering/Construction Division, LLNL, March 27, 1989 (with May 25, 1989 Rev.)
"Construction Manager Manual, Subcontracted Construction Projects," Plant Engineering Department, LLNL, W. Kleck, January 1989
"Construction Inspector's Policy and Procedures Manual," Plant Engineering Department, LLNL (July 1984)
LLNL "Health and Safety Manual" (M010)
Electronics Engineering / Instrument Services Calibration and Certification Manual, LER 87-1007-99
Quality Assurance Plan for Calibration Services, Engineering Measurements and Analysis Section, Engineering Sciences Division, M.E.
LLNL Management Policy Memorandum MPM 02.2 "National Environmental Policy Act (NEPA) Compliance"
DOE Order 4330.4A, Real Property Maintenance Management
Plant Engineering (PE) QA Program Plan
PE QA Manual PEL-P-01010
LLNL Environmental Protection Handbook, issued by the Environmental Protection Department
PE Policy and Operations Manual PEL-P-01000
PE Specifications, PEL-P-02075
PE Maintenance and Operations QA Plan, M-078-30.6
PE Maintenance and Operations Electric Utilities QA Plan, M-078-30.10
PE Maintenance Services/Operations QA Plan, M-078-30.9
PE Maintenance and Operations Utilities QA Plan, M-078-30.7
PE Maintenance and Operations Maintenance Engineering and Production Control QA Plan, M-078-30.8
PE Maintenance and Operations Electric Utilities QA Plan, M-078-30.10

Table F-2. Required QA records.

QA files	QA record title	Person responsible
TF518-2-1	Personnel Training Records	QAM
TF518-3-1	Design Criteria	PEPE
TF518-3-2	Design Calculations	PEPE
TF518-3-3a	Design Changes	PEPE
TF518-3-3b	Specifications	PEPE
TF518-3-4a	Drawing List	PEPM
TF518-3-4b	Specifications List	PEPM
TF518-3-6	NEPA Compliance Documents	PEPM
TF518-4-1	Design or Construction Purchase Orders	PEPM
TF518-5	Work Performance and Facility Operations Log	OTL
TF518-6-1	As-Built Prints	CM
TF518-7-1	Notice of Completion	CM
TF518-9-1	Welder Certification	CI
TF518-9-2	Welding Test Reports	CI
TF518-9-3	Cemented Joints Test Reports	CI
TF518-10-1	Inspection Prints	CI
TF518-10-2	Final Inspection Report	CI
TF518-10-3	Final Acceptance Report	CI
TF518-18-1	Audit Requests and Reports	PEPM

Table F-3. Applicability of NQA-1 Elements to the Quality Assurance of the B-518 Vapor Treatment Facility.

NQA-1 requirement	Title	Applicable ?
Basic 1	Organization	Y
Supplement S-1	Terms and Definitions	Y
Supplement 1S-1	Supplementary Requirements for Organization	N
Basic 2	Quality Assurance Program	Y
Supplement 2S-1	Supplementary Requirements for the Qualification of Inspection and Test Personnel	N
Supplement 2S-2	Supplementary Requirements for the Qualification of Nondestructive Examination Personnel	N
Supplement 2S-3	Supplementary Requirements for the Qualification of Quality Assurance Program Audit Personnel	N
Supplement 2S-4	Supplementary Requirements for Personnel Indoctrination and Training	N
Basic 3	Design Control	Y
Supplement 3S-1	Supplementary Requirements for Design Control	N
Basic 4	Procurement Document Control	Y
Supplement 4S-1	Supplementary Requirements forProcurement Document Control	N
Basic 5	Instructions, Procedures, and Drawings	Y
Basic 6	Document Control	Y
Supplement 6S-1	Supplementary Requirements for Document Control	N
Basic 7	Control of Purchased Items and Services	Y
Supplement 7S-1	Supplementary Requirements for Control of Purchased Items and Services	N
Basic 8	Identification and Control of Items	Y
Supplement 8S-1	Supplementary Requirements for Identification and Control of Items	N
Basic 9	Control of Processes	Y
Supplement 9S-1	Supplementary Requirements for Control of Processes	N
Basic 10	Inspection	Y
Supplement 10S-1	Supplementary Requirements for Inspection	N
Basic 11	Test Control	Y
Supplement 11S-1	Supplementary Requirements for Test Control	N
Supplement 11S-2	Supplementary Requirements for Computer Program Testing	N
Basic 12	Control of Measuring and Test Equipment	Y
Supplement 12S-1	Supplementary Requirements for Control of Measuring and Test Equipment	N

Table F-3. (Continued)

NQA-1 requirement	Title	Applicable ?
Basic 13	**Handling, Storage, and Shipping**	**Y**
Supplement 13S-1	**Supplementary Requirements for Handling Storage and Shipping**	**N**
Basic 14	**Inspection, Test, and Operating Status**	**Y**
Basic 15	**Control of Nonconforming Items**	**Y**
Supplement 15S-1	**Supplementary Requirements for the Control of Nonconforming Items**	**N**
Basic 16	**Corrective Action**	**Y**
Basic 17	**Quality Assurance Records**	**Y**
Supplement 17S-1	**Supplementary Requirements for Quality Assurance Records**	**N**
Basic 18	**Audits**	**Y**
Supplement 18S-1	**Supplementary Requirements for Audits**	**N**

F-4. Operations and Maintenance

F-4.1. Scope

The B-518 Vapor Treatment Facility will be operated to extract and treat soil vapor containing VOCs. The vapor will be treated to meet the requirements specified by the BAAQMD (Appendix E). Therefore, O&M activities at this facility shall be controlled by quality procedures.

F-4.2. Operations

The LSRSL is responsible for ensuring the quality of operations at this facility. The OTL is responsible for ensuring that all field operations, including maintenance and operations, are performed with the appropriate quality procedures and are completed in a timely fashion. The treatment facility, per its respective permit, has a required Self-Monitoring Program. This involves collecting air samples for BAAQMD to monitor the performance of the treatment facility. The OTL is responsible for ensuring that the technicians are properly trained to collect these samples according to documented procedures.

The B-518 Vapor Treatment Facility has its own set of operating procedures. These procedures, which are being developed, cover the different modes of operation including startup and shutdown and will be described in the B-518 Vapor Treatment Facility operating procedures manual.

A daily operational log is kept at the facility. This log records the operating parameters of each system (i.e., temperature, pressure, etc.), the number and type of samples taken, all maintenance performed on the system, and all adjustments made by the operators to the system.

F-4.3. Maintenance

Two types of maintenance are performed at the B-518 Vapor Treatment Facility:

- Preventive.
- Corrective.

F-4.3.1. Preventive Maintenance

Preventive maintenance is performed on those components that need routine servicing and are part of systems related to quality. The preventive maintenance schedule is kept at each facility with the operations procedures for the B-518 Vapor Treatment Facility. The OTL is responsible for ensuring that the preventive maintenance items are scheduled and completed. Maintenance is performed by LLNL Plant Operations and/or ERD personnel and follows the QA/QC manual to ensure quality maintenance is performed.

Table F-4 is a tentative schedule of the preventive maintenance for the B-518 Vapor Treatment Facility.

Table F-4. Preventive maintenance for the B-518 Vapor Treatment Facility.

Action	Frequency/comments
Inspect vacuum gauges	Daily
Replace GAC canisters	As needed
Sample effluent	As required by BAAQMD
Clean organic debris from area surrounding the building	Weekly, or as needed. Notify the gardeners (Ext. 3-0495)
Inspect vapor flow meters	Daily
Monitor water level switch in the demister	Daily
Monitor temperature switches in the piping	Daily
Monitor pressure switches in the piping	Daily
Service blower motor	Annually. Motor to be serviced by Plant Engineering motor shop (Ext. 2-7751), Bldg. 511
Inspect air-to-air heat exchanger	Daily
Inspect demister cyclone	Daily
Inspect miscellaneous hoses, seals, fittings, etc.	Weekly

F-4.3.2. Corrective Maintenance

Corrective maintenance is performed when a system component fails or is beginning to fail and the quality of facility operations could be compromised if operation continues. Root cause analyses are performed each time a component fails before the corrective maintenance action commences. This is to ensure that the nature of the problem is understood and can be prevented. This root cause analysis is also used to modify the preventive maintenance plan where appropriate. The results of the root cause analyses are documented in the daily facility operations log. As with preventive maintenance, corrective maintenance is performed by Plant Operations personnel or ERD in accordance with the QA/QC plan.

All corrective maintenance actions and their times of completion are recorded in the facility daily operations log. Once complete, the specific component or system is started up and operated. This ensures that the maintenance was correctly performed and that system quality is maintained. An entry in the facility log is made, indicating that an operational check was made following preventive or corrective maintenance and the performance of the new component is noted. If successful, the system is allowed to resume normal operations.

When the Operations and Maintenance Manual for the B-518 Vapor Treatment Facility is developed, it will indicate the required spare parts for system components that have relatively high risk of failure or long lead time. These components are to be maintained on site to prevent extended shutdown of the treatment system.

F-4.4. Drawing and Specification

The PEPM is responsible for preparation and updating complete drawing and specification lists. The lists shall include all drawings, specifications, and changes for Purchase Order (PO) contracts, labor only contracts, Job Orders, and Mechanical and Electronic Engineering Department drawings. This list will serve as the index for the QA print files and as the list of prints required in the QA files.

QA records to be filed as required in Table F-2:

(TF518-3-4a) A current and/or final copy of the drawing list.

(TF518-3-4b) A current and/or final copy of the specification list.

F-4.5. National Environmental Policy Act (NEPA)

The PEPM is responsible for assuring compliance with NEPA requirements. Completed documentation consists of LLNL Plant Engineering Form 1, NEPA Compliance Project Notification Form, and the NEPA Compliance Environmental Checklist. Memos to and from DOE, and Environmental Impact Studies, as applicable, are evidence of NEPA compliance.

QA records to be filed as required in Table F-2:

(TF518-3-6) NEPA Compliance Documents.

F-5. Procurement

F-5.1. Procurement Contracts

Preparation and approval of PO contracts, when necessary for the purchase of equipment or services needed for maintenance, shall comply with standard LLNL purchasing policies.

QA records to be filed as required in Table F-2:

(TF518-4-1) Copy of all material and equipment POs over $5,000.

F-5.2. Documents

The approval and control of procurement documents shall conform to LLNL Procurement Manual, Vol. II, Books 1, 2, and 4. The control and approval of maintenance construction drawings shall conform to LLNL Plant Engineering Drafting Manual, PEL-P-02065. Control, format, and approvals of specifications shall conform to Plant Engineering Standard PEL-P-02075 Specifications.

All drawings shall be approved for maintenance construction and have all applicable approval signatures before the bidding process, or, for LLNL construction, before the estimate process. Approvals of major changes to instructions, drawings, and specifications shall be the same as for the original issue.

Minor technical design changes made in the field shall be approved by the CM and the CI on the inspection print, and on the as-built drawings.

QA records to be filed (as required in Table F-2):

(TF518-6-1) One set of as-built prints for each project.

F-5.3. Control of Purchased Items and Services

Purchased items and services shall be controlled in accordance with standard LLNL Purchasing Policies. A Notice of Completion shall be prepared with all required LLNL signature approvals, and sent to the LLNL Procurement Department before contract closeout.

QA records to be filed (as required in Table F-2):

(TF518-7-1) Copy of the Notice of Completion for each project.

F-5.4. Handling, Storage, and Shipping

Items and materials shipped to LLNL shall be packaged, shipped, and stored according to instructions on drawings, specifications, contracts, and POs. The RE or OTL will perform a receiving inspection and/or the CI shall inspect incoming items and materials to identify any damage that may have occurred during shipping and storage.

Handling equipment, such as fork lifts and cranes, shall be operated, maintained, and tested in compliance with DOE and California State regulations. When LLNL equipment is used, compliance with the LLNL Health and Safety Manual is required.

Inspection reports are initiated and maintained per the CI's Policy and Procedures Manual. No additional QA records are required for the QA files.

F-5.5. Control of Nonconforming Items

The CI and CM shall maintain cognizance of salvage (rejected or damaged) materials and items (M&I), and arrange for segregation, and prompt disposition of LLNL-supplied rejected M&I. The construction subcontractor shall be notified to immediately remove any rejected subcontractor supplied M&I from LLNL. Any nonconformance which cannot be immediately corrected and verified by the CI shall be documented on a Deficiency Notice or punch list as applicable. Nonconformances to be dispositioned as “use as is” or “repair” (as opposed to rework) must be recorded on a Deficiency Report, approved and signed by the CM.

Inspection reports are initiated and maintained per the CI’s Policy and Procedures Manual. No additional QA records are required for the QA files.

F-6. Maintenance Support

F-6.1. Identification and Control of Items

Material delivered to the job site is inspected to verify compliance with the approved submittals to assure that only correct and accepted items are used or installed.

The CM will request identification and inspection of items arriving at the construction site, when required. Acceptance of M&I not in conformance with requirements shall be approved by the LSRSL and PEPE, and shall comply with the LLNL Procurement Manual.

Inspection reports are initiated and maintained per the CI’s Policy and Procedures Manual. No additional QA records are required for the QA files.

F-6.2. Inspection, Test, and Operating Status

The CI and CM shall maintain cognizance of incoming and stored M&I, and inspect or test them for conformance to requirements. When the CI or CM is concerned with maintaining identification of the status of a shipment of critical M&I, they shall tag the affected items to ensure that untested or rejected items are not inadvertently used.

Lockout tags shall be tied on electrical equipment, lifts and hoists, valves, etc., where such items are unsafe to use, are uncertified, or to protect personnel working on the system.

Inspection reports are initiated and maintained per the CI’s Policy and Procedures Manual. No additional QA records are required for the QA files.

F-6.3. Control of Processes

Procedures for welding, bonding, and other processes shall be called out in specifications or drawings, as required.

When required in construction specifications, bonded joints, welding tests, and inspections, welder certifications shall be verified by the CM and the CI, as required.

QA records to be filed (as required in Table F-2):

(TF518-9-1) Welder certifications.

(TF518-9-2) Welding test reports.

(TF518-9-3) Cemented joints test reports.

F-6.4. Inspection

All maintenance work, and LLNL acceptances within the scope of this QA plan, including PO contract and labor only contract are subjected to inspection. Work shall be inspected and documented according to the "Construction Inspector's Policy and Procedures Manual" and the "Construction Manager Manual." The inspection team shall delay progress payments to the subcontractor if the work is not in place, or is not up to contract quality.

During construction of modifications, the CI shall maintain a set of as-built marked prints to compare with the subcontractor's prints, and shall review and approve the subcontractor's prints.

After construction, the CI shall verify the accuracy of the as-built drawings in accordance with the "Construction Inspector's Policy and Procedures Manual." The CI and PEPM shall indicate approval of the subcontractors marked up print by signing the as-built drawing.

QA records to be filed (as required in Table F-2):

(TF518-10-1) All inspection prints, with copies of field memos, change orders, calculations, and sketches attached.

(TF518-10-2) Final inspection report per Construction Manager Manual.

(TF518-10-3) Final acceptance report per Construction Manager Manual.

F-6.5. Control of Measuring and Test Equipment

Certified testing laboratory subcontractors shall periodically calibrate measuring and test equipment used for LLNL work according to the requirements in the contract and according to Federal and State codes.

F-7. Activation

F-7.1. Activation of Measuring and Testing Equipment

All Measuring and Test Equipment (M&TE) used in acceptance testing of quality affecting electronic, monitoring, and interlock systems and components shall be calibrated in accordance with the applicable LLNL calibration manual or plan. The individual conducting the test shall be responsible for assuring that all test equipment is calibrated and within its certification period.

The two major calibration laboratories at LLNL are the Engineering Measurements & Analysis Section, Mechanical Engineering (ME), and the Instrument Services Group, Engineering Services Division, Electronic Engineering (EE). The ME facility typically calibrates M&TE that make pressure, force, displacement, flow, humidity, acceleration, velocity, or temperature measurements. The EE facility services and calibrates M&TE that measures frequency, time, and electrical and magnetic measurements.

Calibration of M&TE may be performed by LLNL calibration laboratories or by outside vendors providing calibration services. Vendors providing calibration shall be required to meet the requirements of MIL-STD-45662, where necessary.

No additional QA records are required in QA files, but such records are filed in the EE and ME calibration facilities.

F-8. Quality Assurance Records

F-8.1. Quality Assurance Records

QA records shall be prepared, archived, and made readily available as evidence that the B-518 Vapor Treatment Facility was specified, designed, constructed, operated, and maintained to meet the quality goals of this QA plan. They shall be protected and maintained for a minimum of 6 months after completion of the project prior to being microfilmed and archived for long-term storage.

The QA records specified by this plan do not include all the project records generated in the project. In addition to the QA records, there are microfilmed records maintained by LLNL Plant Engineering, and contract records maintained by the LLNL Procurement Department. Although these records are not defined as QA records, they are available for examination if required.

F-8.2. Filing Systems

QA records required by this plan shall be filed in lockable cabinets in the order in Table F-2. Before filing, each record shall be numbered and titled according to Table F-2, and stamped with a black ink stamp:

QA RECORD

QA PLAN NO. X-XXX-XX

DATE:__________

A file drawer insert shall be set up and labeled for each file number, and each record shall be placed in a labeled folder or binder and kept in the QAM’s office. QA records are not working files, and shall not be so utilized. If files are borrowed, a file checkout system shall be used to track record location and to ensure their prompt return.

F-8.3. Plant Engineering Records

In addition to the separate QA records file of this QA plan, the PEPM, PE, CM, and CI shall organize and maintain working engineering files for the project. These files are not QA records files; they are files normally kept when required for compliance or legal purposes. Records, as specified in the CM Manual and the Construction Inspector's Manual, shall be collected by the CM, CI, and the PEPE, and transmitted by the PEPM to the Standards and Documentation group of Plant Engineering for microfilming. These files shall be preserved for a period of not less than 6 years after project completion.

F-9. Audits

The PEPM shall arrange for periodic independent audits of the implementation of this QA plan.

QA records to be filed:

(TF518-18-1) Audit requests and reports.

F-10. References

American Society of Mechanical Engineers (ASME) (1989), NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*, ASME NQA-1-1989 edition.

MIL-STD-45662, “Calibration System Requirements.”

PEL-01000, “Plant Engineering Policy and Operations Manual.”

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Appendix G

Operations and Maintenance Health and Safety Plan

Appendix G
Operations and Maintenance Health and Safety Plan

G-1. Reason for Issue

Safety procedures are required to operate and maintain the B-518 Vapor Treatment Facility. This HASP also serves as an administrative tool to summarize many of the requirements of the LLNL Health and Safety Manual which are pertinent to the B-518 Vapor Treatment Facility operation and maintenance.

G-2. Work to be Done and Location of Activity

G-2.1.

The B-518 Vapor Treatment Facility, when constructed, will be located southeast of B-518.

G-2.2.

Contaminated soil vapor containing VOCs is extracted from designated vapor extraction wells.

G-2.3.

The influent vapor stream is passed through a demister to separate water mist from vapor.

G-2.4.

The separated vapor stream containing VOCs is forced by a blower to pass through three 55-gal drums containing GAC.

G-2.5.

The GAC adsorbs the VOCs. The cleaned vapor is released to the environment and is monitored to ensure compliance with BAAQMD emission requirements.

G-3. Responsibilities

G-3.1.

Ed Folsom, phone number (510) 422-0389, LLNL pager number 02892, and home phone number (510) 490-7028, is responsible for the safety of this operation and for assuring that all work is performed in conformance with this HASP and applicable sections of the LLNL Health and Safety Manual and Environmental Protection Handbook. In the absence of the responsible individual, Jerry Duarte, phone number (510) 423-2638, LLNL pager number 03180, shall assume these responsibilities.

G-3.2.

Any changes in operations that improve or do not significantly affect safety and environmental controls may be approved by the authorizing individuals in Section G-3.1. and the LLNL Environmental Safety & Health (ES&H) team leader. The responsible individual will ensure that this action is documented in a memorandum. Any changes in the operation that increase the hazard level, introduce additional hazards, or decrease safety shall not be made until a revision to this HASP has been reviewed and approved consistent with the review and approval process of the original HASP.

G-3.3.

Before starting operation, the responsible individual shall verify and document that the operating personnel have read and understand this HASP.

G-4. Hazard Analysis

G-4.1. Electrical Hazard

A 440-volt alternating current electrical power supply is used to operate this facility. Electrical shock and injury may occur if personnel come into contact with exposed wiring. Unauthorized access to the electrical panel is prevented by keyed locks.

G-4.2. Seismic Hazard

Personnel may be injured during an earthquake due to falling equipment or missile hazards (equipment or materials moving energetically due to seismic forces).

G-4.3. Confined Space

Not applicable.

G-4.4. Noise Hazard

Injury may occur due to continuous exposure to the operating blower.

G-4.5. Fire/Explosion

Not applicable because VOC concentrations are at least two orders of magnitude below the lower explosive limit.

G-4.6. Chemicals

Not applicable.

G-5. Hazard Control

G-5.1. Electrical Hazard Control

G-5.1.1.

An interlock system and panel doors with keyed locks prevent contact with energized electrical components. The keys to panel door locks are kept in a lock box in the B-518 Vapor Treatment Facility.

G-5.1.2.

All personnel will follow safety precautions as outlined in the Health and Safety Manual, Chapter 23, "Electricity," and the Electronics Engineering Department- Electrical Safety Policy, LED-61-00-01-A1A.

G-5.2. Seismic Hazard Control

G-5.2.1.

Equipment will remain securely bolted to concrete pads to avoid damage and injury during an earthquake.

G-5.2.2.

To preclude injury from missile hazards (equipment or materials moving energetically due to seismic forces), equipment and materials stored at a height of 5 ft or more shall be restrained.

G-5.3. Noise Control

During the initial operation of the B-518 Vapor Treatment Facility, Hazards Control ES&H Team 4 shall be contacted to arrange for a baseline noise survey. If 8-h time weighted average (TWA) noise exposures are projected to approach or exceed 85 dB(A), the following shall be enforced:

G-5.3.1.

Entrance to the area shall be posted with “Noise Hazard” warning signs.

G-5.3.2.

LLNL personnel shall be enrolled in the LLNL Hearing Conservation Program.

G-5.3.3.

Supplemental labor providers with personnel working within the facility shall be advised to enroll their employees in their company's Hearing Conservation Program.

G-5.3.4.

Other subcontractors shall be notified of the presence of potentially hazardous noise levels and advised to enroll employees in their company's Hearing Conservation Program.

G-5.3.5.

All employees within the facility shall receive Hazards Control course HS-4360—"Noise."

G-5.3.6.

All employees shall wear hearing protection when working within the hazardous noise area.

G-6. Environmental Concerns and Controls

Concern: Atmospheric discharge of untreated vapor.

Controls:

- Scheduled sampling per discharge permit and self-monitoring requirements.
- Daily inspection for leaks by the facility operator.
- When contaminants break through the first carbon filter, the influent vapor continues to be adsorbed onto the second or third carbon filter.
- All piping containing untreated vapor is under vacuum so that leakage can only go into the pipe, and cannot be released to the atmosphere.

G-7. Training

G-7.1. Basic Facility Operator Courses:

- HS-0039—SARA/OSHA Training (40-h course with yearly refreshers).
- HS-0001—New Employee Safety Orientation.
- HS-1620—Standard First Aid (First Aid Certification valid for 3 y)
- HS-1640—Cardiopulmonary Resuscitation (CPR) (CPR Certification valid for 1 y)
- HS-5300—Back Care Workshop
- HS-4360—"Noise" if 8-h TWA noise exposures exceed 85 dB(A).

G-7.2.

Facility Operator Courses:

- HS-0006—Hazardous Waste Handling Practices (refresher training required annually)
- HS-4150—Confined Space
- HS-4240—Chemical Safety
- HS-4360—Noise Safety (required annually for those exposed to high noise)
- HS-5030—Pressure Orientation (required every 5 y)
- HS-5210—Capacitor Safety (required every 5 y)
- HS-5220—Electrical Safety (required every 5 y)
- HS-5230—High Voltage Safety
- HS-5245—Lock and Tag Procedure (refresher training required whenever there is a change in job assignments, a change in equipment or process that presents a new hazard, or when there is a change in the Energy Control Procedure)
- HS-6010—Radiation Safety (required every 2 y)

G-7.3.

The training courses identified in this section do not qualify a person to operate the treatment equipment and treatment systems. Only the responsible individual identified in Section G.3 of this HASP will determine if and when a person is qualified to operate the B-518 Vapor Treatment Facility. Once qualified, each technician's personnel file is updated to reflect their status as a treatment facility operator.

G-7.4.

The responsible individual, or designee, shall ensure that all required training (including on-the-job training if applicable) is completed and documented. Untrained personnel may work under the supervision of a trained person until the required training is completed.

G-8. Maintenance

High-voltage interlocks shall be function tested quarterly as required by the LLNL Health and Safety Manual, Section 23.33.

G-9. Quality Assurance

G-9.1.

Quarterly interlock function checks shall be performed by the Facility Electronics Staff assisted by operators as required. Test documentation shall be maintained by the Facility Electronics Supervisor, or designee.

G-9.2.

The scheduled weekly, monthly, quarterly, and annual sampling ensure compliance and quality.

G-10. Emergency Response Procedures

In the event of an emergency, facility operations personnel will first dial “911” to report to the Emergency Dispatcher, then administer first aid if necessary to injured personnel. The Emergency Dispatcher uses reserved telephone lines to promptly relay the emergency call to the following members of the LLNL Emergency Response Team:

- Fire Department.
- Security Department.
- Hazards Control Safety Teams.
- Plant Engineering.
- Health Services.

The Emergency Response Team will go to the scene of the emergency immediately. During off-shift hours, the phone numbers of individuals to be notified in the event of an emergency will be posted at the B-518 Vapor Treatment Facility. The LLNL Health and Safety Plan describes the emergency response procedures.

G-11. References

G-11.1. Health and Safety Manual Sections

1. LLNL General Policies and Responsibilities
2. Work Planning, Safety Procedures, and Management Oversight

10.08 Hearing Protection

21. Chemicals

21.04 Facilities and Equipment

21.05 Handling Solid and Liquid Chemicals

23. Electricity

23.01 Introduction

23.02 Biological Effects of Electrical Hazards

23.03 Emergency Assistance and Rescue

23.04 Personal Protective Equipment

23.05 Design and Documentation of Electrical Equipment

23.06 Training Requirements for Electrical Work

23.10 General Practices for Work on Electrical Equipment

23.13 Work on Other Electrical Apparatus and Systems

23.20 Clearances and Illumination for Electrical Enclosures

23.21 Power Disconnect Points

23.23 Extension Cords

23.30 Portable Electric Tools and Equipment

23.33 Interlocks

23.35 Power Supplies

23.36 Microwave and Electromagnetic Sources

23.37 Electromagnets and Inductors

23.38 Batteries

23.39 Capacitors

26.14 Working in Confined Spaces

G-11.2. Electronics Engineering Department- Electrical Safety Policy, LED-61-00-01-A1A

G-11.3. LLNL Health and Safety Manual Supplements:

11.07 Personnel Safety Interlocks

11.08 Noise- Its Measurements, Evaluation, and Control

26.13 General Lockout and Tagout Procedure

G-12. Reviewers

The following are the reviewers for issues in this HASP related to health and safety.

Facility Supervisor.

Section Head or Group Leader.

Hazard Control Safety Team 4.

Individual assigned responsibility for safety.

Division/Department who authorized HASP.

Supervisor of matrixed technical personnel.

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Appendix H

B-518 Vapor Treatment Facility Sampling Procedures

Appendix H
B-518 Vapor Treatment Facility Sampling Procedures

Prior to discharge, vapor samples will be collected and analyzed at a sample location upstream of the B-518 Vapor Treatment Facility discharge five times per week using an OVA/FID as discussed in Section 4.2. To determine the amount of methane in the discharge, readings will be taken with and without a carbon filter tip on the OVA/FID. Prior to collecting a sample, the office preparation procedures described in SOP No. 4.1— "General Instructions for Field Personnel" and SOP No. 4.2— "Sample Control and Documentation" (Rice *et al.*, 1990) will be followed.

Influent vapor samples will be collected in 0.5-liter (L) stainless steel gas sampling spheres. The spheres have two valved ports, one on each end. One port is connected to the sampling port on the pipeline to be sampled, and the other to a 0.125-horsepower, 0.25-scfm vacuum pump exhausted to the atmosphere. The vacuum pump is positioned downstream from the sampling container to prevent chemical alteration of the vapor sample.

To draw an influent sample, all three ports are opened (the sampling port and both ports on the sampling sphere) and the vacuum pump is operated long enough to purge a minimum of five sampling-sphere volumes (3 to 4 L are purged in 15 seconds). The pump is then turned off, the ports are quickly closed, and the sampling sphere is shipped to an analytical laboratory according to SOP N. 4.4—"Guide to the Handling, Packaging, and Shipping of Samples" (Rice *et al.*, 1990).

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Plate 1*: P&ID Location Plan for Treatment Facility B518

***NOTICE: Plate 1 exists only**
in hard copy. Hard copies can be obtained
in ERD's Trailer 4302 Library.